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Technical activities for the period October 1 through December 31, 1968 are covered. Described are the development, implementation, interim evaluation, and probable future applications of the first and second level electronics curriculums. One hundred and sixty-nine electro-electronic job titles were identified; tasks within these were classified as basic, speciality, advanced, ancillary, or redundant to differentiate them from more elementary or more specialized skills. Objectives containing the knowledge, skills, conditions and criteria were then prepared. Self-study course materials were developed based on the objectives for the first level occupation, General Assembler. Tests were provided for end-of-unit and end-of-course proficiency evaluation. A student-instructor ratio of 18 to 1 proved satisfactory in this situation, which involved most students working in pairs at work stations. "First attempt" performance varied from 100 percent to 24 percent across the performance objectives. The appendix includes a chart of the occupational cluster; sample instructional units; lists of units, objectives, and tasks; and sample tests. (EM)

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ELEVENTH QUARTERLY TECHNICAL REPORT

Project No. 5-0009

Contract No. OE-5-85-019

DEVELOPMENT AND EVALUATION OF AN EXPERIMENTAL CURRICULUM FOR THE NEW QUINCY (MASS.) VOCATIONAL-TECHNICAL SCHOOL

The Electronics Curriculum

31 January 1969

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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American Institutes for Research
Pittsburgh, Pennsylvania

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FOREWORD

This report, submitted in compliance with Article 3 of the contract, reports on technical activities of Project ABLE during its eleventh quarter of operation, 1 October through 31 December 1968. A brief overview of the project is presented first, followed by a report summary. The major sections of the report concern (a) the derivation of objectives for grades 10 and 11, and (b) the implementation and present evaluation of the grade 11 curriculum.

OVERVIEW: Project ABLE

A Joint Research Project of: Public Schools of Quincy, Massachusetts
and American Institutes for Research

Title: DEVELOPMENT AND EVALUATION OF AN EXPERIMENTAL CURRICULUM FOR THE NEW QUINCY (MASS.) VOCATIONAL-TECHNICAL SCHOOL

Objectives: The principal goal of the project is to demonstrate increased effectiveness of instruction whose content is explicitly derived from analysis of desired behavior after graduation, and which, in addition, attempts to apply newly developed educational technology to the design, conduct, and evaluation of vocational education. Included in this new technology are methods of defining educational objectives, deriving topical content for courses, preparation of students in prerequisite knowledges and attitudes, individualizing instruction, measuring student achievement, and establishing a system for evaluating program results in terms of outcomes following graduation.

Procedure: The procedure begins with the collection of vocational information for representative jobs in eleven different vocational areas. Analysis will then be made of the performances required for job execution, resulting in descriptions of essential classes of performance which need to be learned. On the basis of this information, a panel of educational and vocational scholars will develop recommended objectives for a vocational curriculum which incorporates the goals of (1) vocational competence; (2) responsible citizenship; and (3) individual self-fulfillment. A curriculum then will be designed in topic form to provide for comprehensiveness, and also for flexibility of coverage, for each of the vocational areas. Guidance programs and prerequisite instruction to prepare junior high students also will be designed. Selection of instructional materials, methods, and aids, and design of materials when required, will also be undertaken. An important step will be the development of performance measures tied to the objectives of instruction. Methods of instruction will be devised to make possible individualized student progression and selection of alternative programs, and teacher-training materials will be developed to accomplish inservice teacher education of Quincy School Personnel. A plan will be developed for conducting program evaluation not only in terms of end-of-year examinations, but also in terms of continuing follow-up of outcomes after graduation.

Time Schedule: Begin 1 April 1965
Complete 31 March 1970
Present Grant -- 1 October 1968 to 30 September 1969

REPORT SUMMARY

This report describes the development, implementation, interim evaluation, and the probable future of the Project ABLE first and second level electronics curricula. The development stage of the project included the selection of jobs for training, the analysis of incumbent tasks, and the stating of course objectives in behavioral terms. The development stage was completed with the preparation of instructional materials which would lead the student, at his own rate, to the accomplishment of the stated objectives.

Implementation of the program, with continuing student and material evaluation, was the next phase (and well underway at the time of the preparation of this report). Most of the 18 students involved have accepted the responsibility for learning, and have demonstrated improved work and study habits. Student interest and progress is encouraging even to the casual observer. The attainment of objectives according to available data, has in some cases been lower than the established standards. However, revisions of the study materials and a refinement of the performance evaluations, according to recent tests, should remedy the problem areas.

Evaluation and revision of the materials on the basis of performance data will take place upon completion of the 1968-69 school year. Revised programs for 1969-70 will be operational for all first and second level students. The third level programs are presently under development and will undergo a limited test during the 1969-70 school year. Implementation of operational programs for fall of 1969 will include: (1) a non-graded electronics department for vertical and horizontal transfer irrespective of the school calendar, (2) a flexible program of individualized scheduling and course selection, (3) a limited test of the third level radio-television repairman and electronics technician programs, (4) the beginning of a third level cooperative work study program.

RATIONALE FOR THE ELECTRONICS CURRICULUM

All occupations in the electronics industry as listed in the Dictionary of Occupational Titles (D.O.T.) were first identified. This included both production and maintenance or repair occupations. Although current training in the Vocational-Technical School focuses on the latter, production occupations were also considered. A survey indicated that there are numerous occupational opportunities with persistent labor shortages in the production field throughout the metropolitan Boston area. Furthermore, production occupations provide for many appropriate exit points at the lower levels of the electronics job family hierarchy.

Occupations requiring at least a baccalaureate were excluded from the sample since the entry requirements at the baccalaureate level are appropriate only to a minority of Vocational-Technical School students. It is evident, however, that selected tasks would be appropriate for students seeking training beyond that of the general target population. A fully operational program of individualized instruction with adequate reference material, should meet a variety of student needs and career aspirations.

The identified occupations were first classified according to the D.O.T. skill levels and then categorized by activities involving data, people, and things. For the most part, only the "data and things" categories apply to the occupations in the electronics family. At the lower occupational levels, the skill requirements are reflected primarily in the "things" categories. However, the requirements become more stringent within the "data" categories as one moves up in the job hierarchy.

As a part of the job analysis, the worker traits and requirements listed in Volume II of the D.O.T. were investigated. The typical training time requirements for each occupation were also identified. The analysis provided further data for identifying the relative position of each occupation within the job family hierarchy.

Occupations recorded on the flow chart (Appendix A) should be considered "milestones" or exit levels within the hierarchy. Furthermore, each "milestone" job is representative of various clusters of occupations. Therefore, the training provided for the selected jobs, should qualify a graduate for entry into other jobs (a sub-family) which have nearly identical or less stringent requirements.

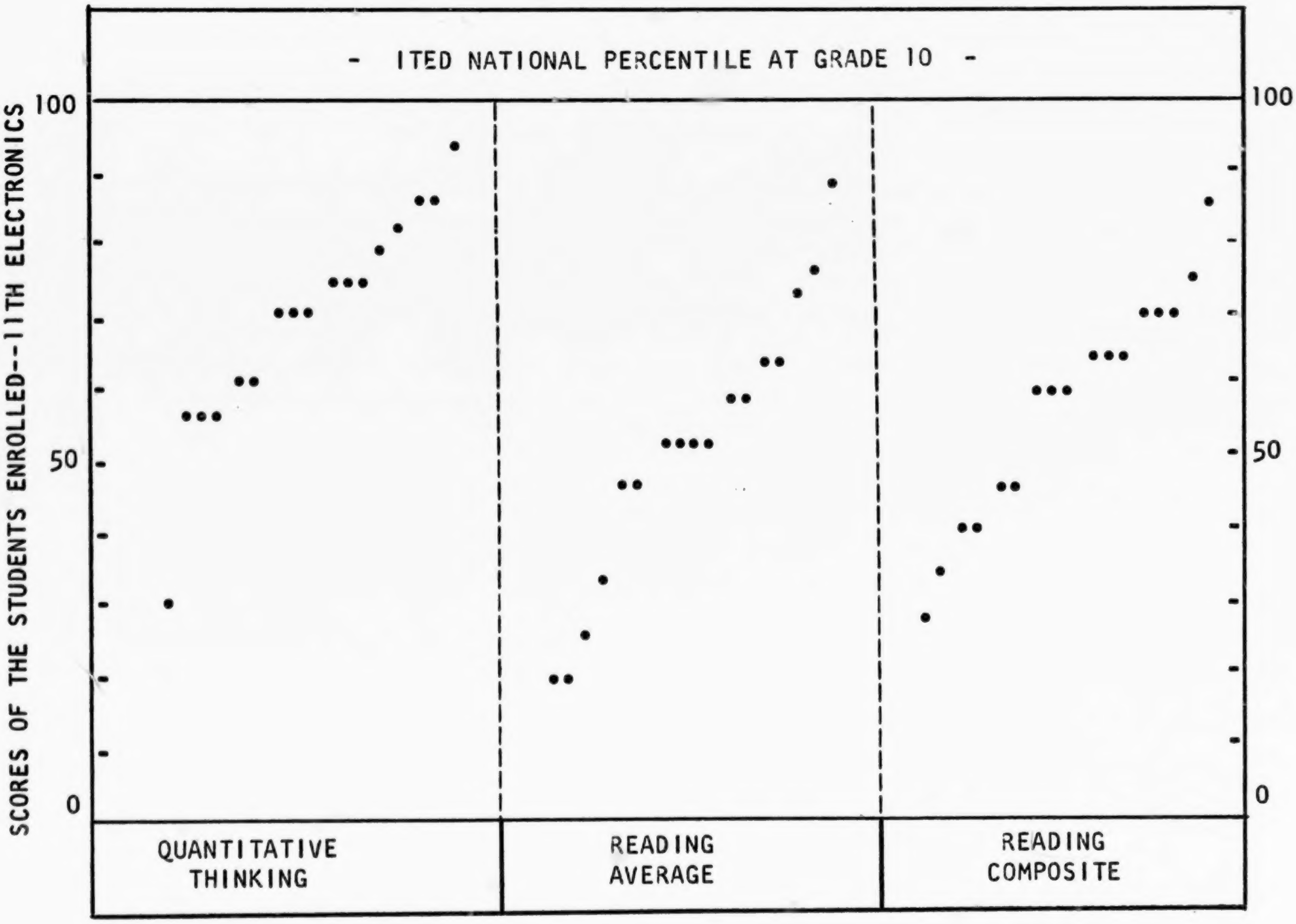
DETERMINATION OF THE VOCATIONAL OBJECTIVES

Target Population

The typical Quincy student enters the 10th grade electro-electronics training program (age 16) with the expectation of securing employment in that field upon completion of grade 12. He enters the program of his choice after undergoing an extensive junior high occupational guidance program which emphasizes career decision-making capabilities. (Project ABLE Fourth and Ninth Quarterly Technical Reports).

Figure 1 depicts Iowa Test of Educational Development (ITED) scores of 17 of the students used in the tryout of second level electronics in relation to the national norms.

Figure 1.



Identification and Selection of Jobs

The identification and selection of jobs followed the guidelines established in the First Quarterly Technical Report.

A list of 169 jobs in the electro-electronic family was compiled from the Dictionary of Occupational Titles for consideration in the study. The process resulted in a manageable list of jobs. Criteria for selection were:

1. Jobs representative of related occupations and requiring performances of a wider variety of tasks and a larger range of skill.
2. Jobs requiring an appropriate (given various limitations of a vocational-technical school program) amount of training time.
3. Jobs having entrance, apprenticeship, or on-the-job training requirements which could be met better as a result of the vocational training to be made available in Quincy (or a typical area vocational-technical school).
4. Jobs appropriate with respect to the cost, equipment, space requirements, and projected usage of training facilities and training equipment.
5. Jobs which were predictable with respect to the skills and knowledge which would be required in the immediate future (5 years).
6. Jobs which would meet the current demands and expectations of local employers. An occupational flow chart based upon many of these electro-electronics jobs was prepared and is presented in Appendix A.

As the work progressed, a new and significantly improved edition of the D.O.T. was published, and adopted by the local, state, and national offices of the U. S. Employment Service. A decision was made to use the new reference as the primary source of job descriptions. The subsequent re-evaluation of the eight jobs (first selection) resulted in the second job flow chart (Appendix A). The occupational sample was adjusted for validity at each level.

Further study of the new job descriptions indicated the feasibility of combining the tasks of a number of related occupations for the purpose of designing a "core" course which would be representative of that group. The selected tasks would thus cover middle level occupations. Graduates mastering such tasks would be employable at that exit point. The graduates would also qualify for entry into one of the more sophisticated training programs at the third level. The general assembler occupation (first training level) was most representative of those occupations which encompassed the basic skill requirements for the second level occupations.

A flow chart (Figure 2) based upon such representative jobs and categorized by the D.O.T. skill levels was prepared. These "key" jobs became the basis for a task analysis and the subsequent derivation of the present course objectives in behavioral form.

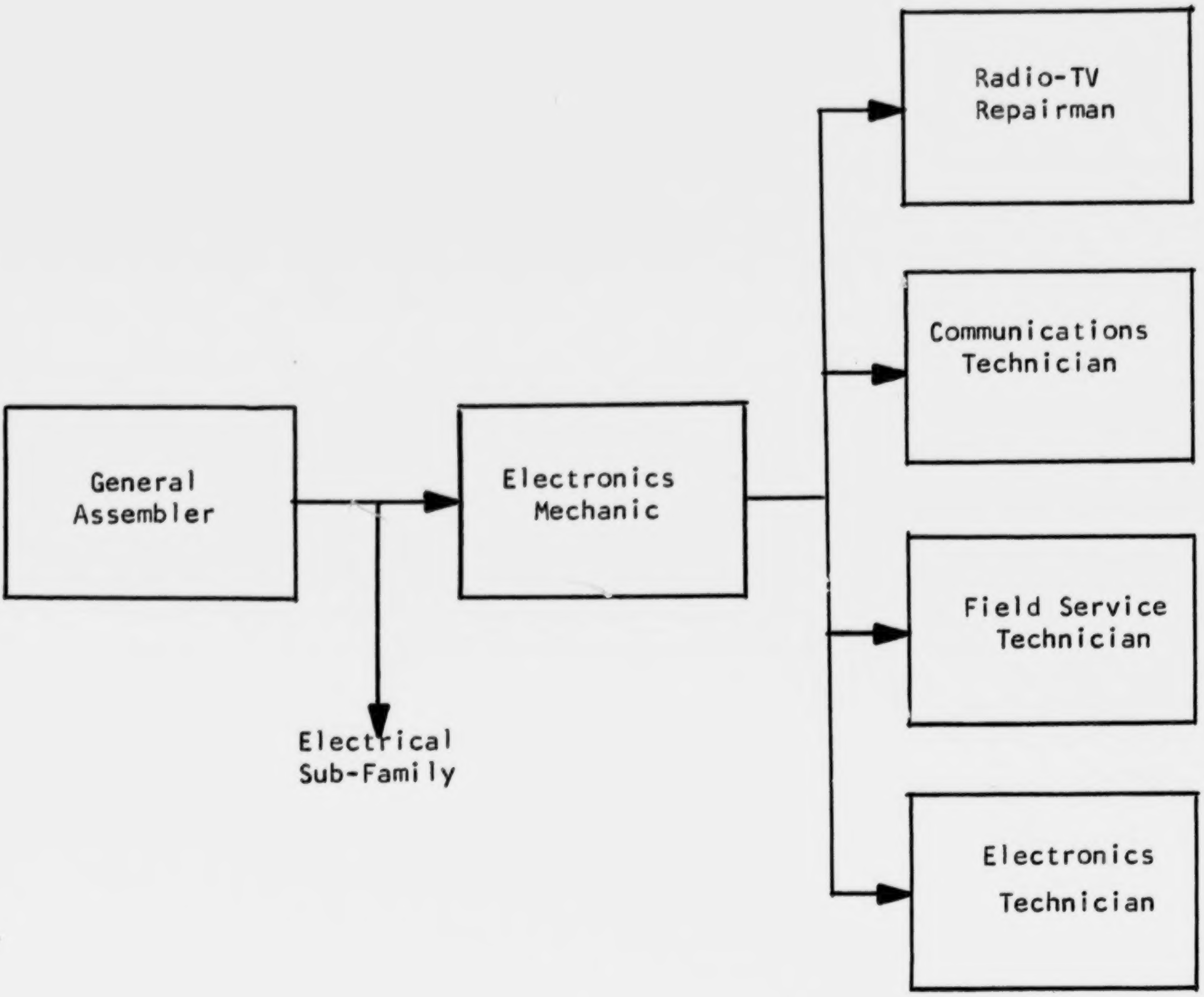

Radio-TV Repairman
Communications Technician
General Assembler
Electronics Mechanic
Field Service Technician
Electrical Sub-Family
Electronics Technician

Figure 2.

Task Analysis and Selection

The next phase of development followed the procedures developed and reported in the Second and Third Quarterly Technical Reports. This effort produced answers to the question, "What do they do?" Two examples of a brief answer would be--"The general assembler installs components and wiring and performs minor testing of electronic assemblies" and "The electronic mechanic services, troubleshoots, and repairs electronics equipment". Because more detail in the breakout of behavioral statements was required, job descriptions (Appendix B) were prepared. Further investigation resulted in the identification of the tasks performed in the normal execution of each job (Appendix C).

The tasks were classified as basic, specialty, advanced, ancillary, or redundant, thus differentiating the appropriate and learnable skills and knowledge from: (1) previously acquired basic skills and (2) the more advanced or highly specialized skills. Standards of performance and working conditions, when included as a part of the task analysis, provided the basis for the identification of course objectives.

Learning Objective Derivation

The objectives as defined in the Second Quarterly Technical Report are "unambiguous statements of successful student performance which include the criteria of success and the important conditions under which the performance is to take place." To write such objectives, the vocational specialists studied each task to determine the capabilities and behaviors required for satisfactory student performance. The knowledge, skills, conditions, and criteria were then presented in precise statements which would clearly communicate to all concerned, the expectations established for the student. A sample topic objective is "Determine the condition of a transistor using an oscilloscope, transistor tester, and trace patterns. Answer will be expressed as good or bad." All the course objectives for the general assembler and electronics mechanic are presented in Appendix D. Appendix E contains the topic objectives of the present electronics mechanic and general assembler curriculum.

DEVELOPMENT OF INSTRUCTIONAL MATERIALS AND METHODS

Developmental Criteria

The criteria established for selection of course materials were:

1. Each unit of instruction should make possible self-study on the part of the student in attaining specific objectives.
2. Each topic's materials should fit in the sequence established for the efficient presentation of training experiences.
3. It should be possible for the student to identify the objective of each topic and to recognize when he had mastered it. (AIR 64)

The materials should include information the student "must know" to perform the objectives. Furthermore, "Nice-to-know" information should be limited. A survey of commercial or other available materials should be conducted. Such materials would be required to meet the specified course objectives established for the Project ABLE curriculum. The materials should be compatable to the Project ABLE methodology and design.

Training Materials for First Level Electronics

A course of instruction is under development for all students entering the first level of the electronics curricula. The course is titled "General Assembler" and is designed for students to learn the skills which are prerequisite for electronics mechanics, repairman, and technicians. Mastering these simpler skills provides each student with the opportunity to see for himself what electronics is all about. Before continuing in the electronics program at a higher level, these students also take a fundamental electrical course. Taking both courses exposes the student to the electronic and electrical career areas before he chooses a definite path for his final two years of vocational training. Off-the-shelf materials were carefully examined for appropriateness, but did not meet the objectives for the first level electronics curriculum. Because individualized self-study materials were not available, a curriculum team, including Mr. Melvin Miller as vocational coordinator, developed the needed instructional program.

The first level program is now being implemented and evaluated, and will be revised as data becomes available. A sample learning unit is included in Appendix F to illustrate the level of technical content contained in the program. The basic skills and knowledge (much recognition as proposed by Gagnė) developed in the first level course, will be put to use immediately upon entry into the second level of the electronics curricula. The second level electronics program has been chosen as the discussion vehicle for this report because it is representative of the type of learning required of trainees in the electronics curricula.

An Existing Self-Instructional Program

Among the materials considered was a learner-centered instruction course, Maintenance Electronics, developed by the Instructional Systems Development Team under the direction of F. Coit Butler at Lowry Air Force Base. At the time of the preparation of this paper, the materials were in use in several Air Force training programs. The system has been described in terms of: (1) a "programmed-instruction....equipment oriented, learn-by-doing curriculum....", (2) where the student uses "....test equipment and hand tools to troubleshoot and repair standard electronic circuits" and (3) each student "works individually and at his own pace...." on "systematized work projects....to achieve each objective". (I.S.D.T. 1966) This program was intended to function as "Core" training system for a number of related electronics repair occupations.

The course in its present form consists of 54 sequenced projects based upon 171 topic objectives. Each project in the workbook provides the student with the objectives, equipment and material requirements, and the step-by-step procedure to accomplish the objectives in a "learn-by-doing" situation. There are no lectures in electronics fundamentals, only self-paced workbench excercises, occasionally supplemented by some work in a programmed text on theory.

The student is continually responding and checking his responses at three different levels of assessment and confirmation. Written responses are required throughout the workbook. The many interim steps have the correct answers supplied "in the open"--the student can confirm his response by simply reading the next sentence.

(For example:)

> From these demonstrations you can say, as temperature
>
> a. increases, diode resistance increases.
> b. decreases, diode resistance decreases.
> c. increases, diode resistance decreases.
> d. decreases, diode resistance is not affected.
>
> Step 4. An increase in temperature causes a decrease in the resistance of a diode. With the 130 Ω 1/10W resistor provided by your instructor, use alligator clips to connect the VOM to read resistance.

On the other hand, terminal behaviors are checked by the "cheat-proof" erasing answer key for self-scoring. (For example:)

> TRAINER CHECK 29. Which of the statements below describes a characteristic of the series circuit?
>
> a. The voltage drop is the same across each resistor.
> b. The total current is the same through each resistor.
> c. The total current varies through each resistor.
> d. All resistors must be equal.

The following page is a sample of the self-scored answers key.

Finally, the student must demonstrate his attainment of the terminal objectives by actually performing the key tasks for the instructor.

> INSTRUCTOR CHECK:
>
> Demonstrate to the instructor the breakdown of a diode due to heat.
>
> INSTRUCTOR'S CHECKLIST
>
> Handled soldering iron safely ________________
> Did not overheat the diode ________________
> Stored soldering properly ________________
> All test equipment
> Switches left in proper position________________
> Leads left in safe place ________________
> Instructor's Initials ________________

TRAINER-TESTER

NAME

GRADE

CLASS

DATE

SUBJECT

TEACHER

Directions: Erase in the rectangle where you think the correct answer is. Preferably use an ink or typewriter eraser or a clean pencil eraser, which is firm and abrasive, and has a reasonably sharp edge. "T" means "right", any other alphabetical response – E, H or L – means "wrong." However, your instructor may choose to designate responses other than "T" as the correct answer responses for a particular exercise. If you uncover other than the response designated as correct, and the instructor wishes you to learn the correct answer, continue erasing until that response is revealed; erase as little as possible.

TEST ITEM	ANSWER FEEDBACK				TEST ITEM	ANSWER FEEDBACK				TEST ITEM	ANSWER FEEDBACK			
	a	b	c	d		a	b	c	d		a	b	c	d
1	■	■	■	■	41	■	■	■	■	81	■	■	■	■
2	■	■	■	■	42	■	■	■	■	82	■	■	■	■
3	■	■	■	■	43	■	■	■	■	83	■	■	■	■
4	■	■	■	■	44	■	■	■	■	84	■	■	■	■
5	■	■	■	■	45	■	■	■	■	85	■	■	■	■
6	■	■	■	■	46	■	■	■	■	86	■	■	■	■
7	■	■	■	■	47	■	■	■	■	87	■	■	■	■
8	■	■	■	■	48	■	■	■	■	88	■	■	■	■
9	■	■	■	■	49	■	■	■	■	89	■	■	■	■
10	■	■	■	■	50	■	■	■	■	90	■	■	■	■
11	■	■	■	■	51	■	■	■	■	91	■	■	■	■
12	■	■	■	■	52	■	■	■	■	92	■	■	■	■
13	■	■	■	■	53	■	■	■	■	93	■	■	■	■
14	■	■	■	■	54	■	■	■	■	94	■	■	■	■
15	■	■	■	■	55	■	■	■	■	95	■	■	■	■
16	■	■	■	■	56	■	■	■	■	96	■	■	■	■
17	■	■	■	■	57	■	■	■	■	97	■	■	■	■
18	■	■	■	■	58	■	■	■	■	98	■	■	■	■
19	■	■	■	■	59	■	■	■	■	99	■	■	■	■
20	■	■	■	■	60	■	■	■	■	100	■	■	■	■
21	■	■	■	■	61	■	■	■	■	101	■	■	■	■
22	■	■	■	■	62	■	■	■	■	102	■	■	■	■
23	■	■	■	■	63	■	■	■	■	103	■	■	■	■
24	■	■	■	■	64	■	■	■	■	104	■	■	■	■
25	■	■	■	■	65	■	■	■	■	105	■	■	■	■
26	■	■	■	■	66	■	■	■	■	106	■	■	■	■
27	■	■	■	■	67	■	■	■	■	107	■	■	■	■
28	■	■	■	■	68	■	■	■	■	108	■	■	■	■
29	■	■	■	■	69	■	■	■	■	109	■	■	■	■
30	■	■	■	■	70	■	■	■	■	110	■	■	■	■
31	■	■	■	■	71	■	■	■	■	111	■	■	■	■
32	■	■	■	■	72	■	■	■	■	112	■	■	■	■
33	■	■	■	■	73	■	■	■	■	113	■	■	■	■
34	■	■	■	■	74	■	■	■	■	114	■	■	■	■
35	■	■	■	■	75	■	■	■	■	115	■	■	■	■
36	■	■	■	■	76	■	■	■	■	116	■	■	■	■
37	■	■	■	■	77	■	■	■	■	117	■	■	■	■
38	■	■	■	■	78	■	■	■	■	118	■	■	■	■
39	■	■	■	■	79	■	■	■	■	119	■	■	■	■
40	■	■	■	■	80	■	■	■	■	120	■	■	■	■

This Trainer-Tester answer sheet was designed to serve the needs of a particular non-profit educational foundation.

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Of course, there are also end-of-the-unit and end-of-the-course criterion tests. (Appendix G) These criterion tests are also performance tests that require the student to demonstrate his proficiency for the instructor.

Revision for Public School Application

Since the program involved "learn-by-doing", considerable reference was made to the operation and application of the test equipment, (and in this case, specific military test equipment). The purchase of such test equipment was neither economically nor educationally feasible because of the cost and the absence of such equipment in civilian industry. The decision was made to revise the materials in order to train students on appropriate equipment used in civilian industry.

It was evident that the revisions should include minor changes in content and the correction of some errors. Upon completion of the first year of implementation, a thorough examination of the program is planned. Data collected during the year along with a review of the objectives and lab operation methods shall determine the nature of any additional revisions. (Anticipated changes in materials and operations are presented as a part of this report.)

Development of Performance Measures

The main consideration in test design was, and continues to be, vocational competance. This can be measured by testing student performance on each objective upon completion of a unit. A training objective restated as a performance test item will provide the most relevant test because it describes the criterion behavior, conditions, and acceptable performance. Care is being taken to insure that the test response duplicates the behaviors required in the stated objective. Questions which require verbalization about a desired performance, rather than the performance itself, have been avoided as much as possible.

Most knowledge test items have multiple choice answers to provide objectivity in scoring. The available incorrect choices were designed to be plausible and logical. Some manipulative skills, such as soldering, are evaluated by using checklists or rating sheets.

Diagnostic performance measurement devices now under development may reveal, for the incoming student, the absence of prerequisite capabilities and/or the presence of advanced capabilities. This will assist in determining the student's starting position within the learning sequence. Upon completion of each learning unit, a performance demonstration determines whether the student should advance to the next unit, repeat the same unit, or be assigned to remedial activities. After a series of units have been completed, additional performance and knowledge tests verify retention of previously demonstrated capabilities.

Curriculum sequence, overall course efficiency, effectiveness, equipment, laboratory and facilities, and the operation in general, are other parameters under scrutiny, especially during the try-out year. Factors including first-test failure rates will provide an indication of learning unit efficiency and are among the revision inputs.

Facilities for the Learning Area

The capability for flexible interaction between the students, lesson materials, training equipment, and the instructor, were established as the criteria for the facilities and room arrangement. The present system enables the instructor to observe all students at all times. The ability to assist individual students while maintaining adequate class supervision was considered essential. The required equipment had to be readily accessible and of sufficient quantity to insure a minimum loss of training efficiency.

It was necessary to design training stations for one or two-student operation. The arrangement of the work area was considered critical to effective training. The work stations presently consist of a two-foot by five-foot work bench with attached sloped-front storage cabinet (Figure 3). By locating the equipment on top of a sloped cabinet, the student can operate the equipment without losing valuable bench space. The resulting equipment elevation with respect to the bench is also ideal for the student's view of equipment, components, and written materials. The elevation permits an unobstructed view of the entire facility for the instructor, and eye-to-eye contact with most students.

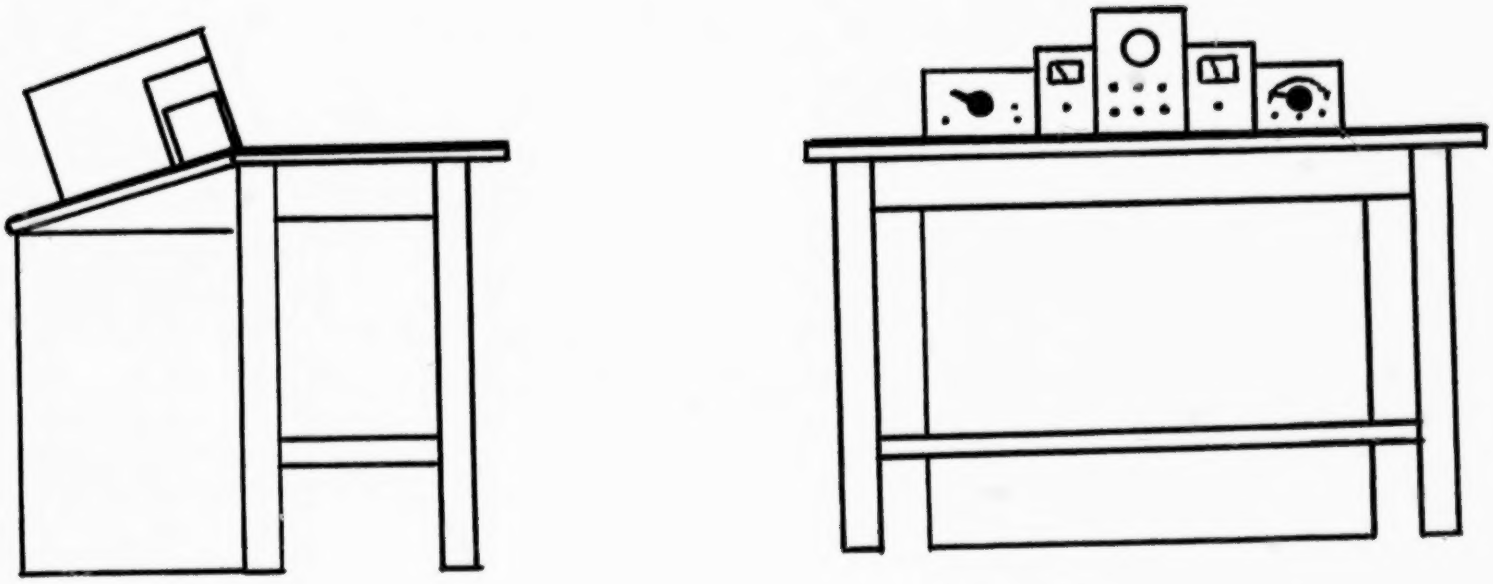

Figure 3.

Equipment requirements were determined from a frequency time chart of projected use. Some equipment, according to the analysis, would be required for each work station. Such items were:

1. Volt-ohm-milliammeter
2. Vacuum tube voltmeter
3. Low voltage power supply
4. Oscilloscope
5. R. F. generator
6. A. F. generator
7. Diagonal cutters
8. Long nose pliers
9. Soldering iron and aids
10. Assorted leads

Other items less frequently used were purchased and stored in cabinets for use by all students, as required.

Printed circuit trainer boards are used by the students for soldering, measuring, troubleshooting, and evaluating vacuum tube and solid state electronic circuitry. There are 22 different trainer models for the program. The board requirements vary from one per station, to one per three stations, depending on frequency of usage. A total of 110 are required for the program. The boards were photo-etched, machined, and assembled by students at the Vocational-Technical school.

The cost figures for the existing Quincy program (excluding benches and cabinets), are as follows:

1. INITIAL INVESTMENT

Per Station: (one or two students per station)

Test equipment	$420
Soldering tools and materials	20
Trainer boards	100

Per Student:

Programmed reference book NYIT	$ 5
1,000 pages of learning units	20

2. ANNUAL COSTS

Per Station:

Test equipment replacement (depreciation)	$ 70
Tool and supply replacements (depreciation)	20

Per Student:

Reference book replacements (depreciation)	$ 2
1,000 pages of learning units (consumable)	20

Initial investment per station = $520
Initial investment per student = $ 25
Annual costs per station = $ 90
Annual costs per student = $ 22

IMPLEMENTATION OF THE INSTRUCTIONAL PACKAGE

Instructor's Role

It became evident quite early in the implementation stage of a student-centered, self-paced training program that the role of the instructor had changed (as contrasted to the more familiar conventional programs). As students progressed through the learning units at varying rates, the instructor had to insure that the required learning materials and equipment were available for every student. Furthermore, the instructor was required to evaluate frequently the proficiency with which students attained the behaviorally stated objectives. (Numerous instructor checks are required throughout the activities.) In addition, students encountering difficulty had to be serviced without delay to maintain student interest and progress. The instructor, in effect, provided the support in the learning environment which assured the necessary interaction between the materials, equipment, and student. The instructor's role is described below as tasks performed.

TASKS PERFORMED BY THE INSTRUCTOR INCLUDE:

1. Assures availability of lesson materials, components, and equipment.
2. Evaluates progress of each student to determine if objectives are attained to stated level of proficiency.
3. Provides assistance, when needed, to enable each student to progress without undue loss of training time or efficiency.
4. Adjusts components of the closed loop instructional system (materials, equipment, students) to assure an optimum level of operation.

Student's Role

The program has, by design, required the student to assume a greater responsibility for his own learning. The nature of the materials encourages the student to develop the initiative to persevere when in difficulty, but to call on the instructor when he is unable to proceed. It has been left to the student to decide when he is ready to demonstrate competence.

One of the most significant attitudinal changes noted was the increased respect for equipment. The responsibility for the care and maintenance of materials and equipment at each work station was assigned to the student/s working at that station. Furthermore, the practice of acceptable work habits was required. One reason for improved student work habits may be that malfunctioning or inaccurate equipment had presented frustrating obstacles in such highly organized curricula. Reduction of such problems for the student requires his careful use of the equipment.

Operation of the Learning Area

There are presently six individual students and six pairs of students at 12 work stations for 2 1/2 hours each day. The 18 students spend the remaining hours each school day attending classes in academic and elected subjects. Each electronics session is devoted entirely to the individualized curriculum. Approximately five minutes is required to set up the work stations and 15 minutes is required to secure and clean the area. Occasional group discussions provide valuable suggestions regarding content, method of instruction, and working environment.

The experiment in grouping seems to indicate that, although many students work best when alone, there is little loss of progress or achievement when working in pairs--if the combinations are carefully made. However, some of the students seem unable to work effectively with others. On the other hand, some appeared to benefit by the pairing. Because of the cost of equipment, the amount of available space, and the projected school enrollment, most students in the future will work in pairs. Some stations will be available for those few students who do not function well with partners. Continual evaluation of the combinations will be necessary, and thus changes can be made when efficiency declines or problems occur.

EVALUATION OF THE INSTRUCTIONAL PACKAGE

Administrative Feasibility

To assure that the new electronics program would be administratively feasible, consideration had to be given to cost, scheduling, staff requirements, grade reporting procedure, and classroom operation.

The students are scheduled for three periods each day under the same procedures used throughout the school. A projected non-graded system (fall 1969) should permit the students to proceed directly from one level of the program to another. This will be an advancement program based upon individual student achievement and performance, rather than grade level and school calendar. No serious problems are anticipated.

A student-instructor ratio of 18 to 1 has proven satisfactory. The State recommends a student-teacher ratio of from 12:1 to 20:1 for shop-type classes. Therefore, the demands on staffing should not be a problem.

Present school grade reporting procedures can be followed, however, the performance data accumulated for each student should provide the vehicle for a long-needed change in reporting procedures. A detailed check list of student behavior and performance (Appendix H) will be used for recording and reporting progress and proficiency at the required tasks. This record, based on the performance objectives of the course, would be made available to parents and prospective employers.

Interaction of instructors, students, learning materials, and equipment has been carefully observed. There is a definite need for documentation of classroom operation. An instructor manual must be prepared and should include topic objectives, required equipment and training aids, average completion times for projects, answers to student test items, identification of learning areas requiring special attention, alternate methods of learning for problem areas, and comments on each unit.

A data book on each student such as that developed for the Project ABLE guidance program should be a part of the electronic program materials. Information which would be helpful would include data on reading comprehension, mathematical reasoning, mechanical aptitude, and various achievement measures. The data book could also be used for recording other student information such as objectives accomplished, time per unit, pass-fail rate, attendance, etc.

Student Attainment of Objectives

Periodic training checks require the student to demonstrate acceptable performance for the objectives completed. The rate of satisfactory performance (first attempt) has varied from 100% on some objectives to 24% for others. The evaluation pass rates (first attempt) for the first ten learning units are presented in Figure 4.

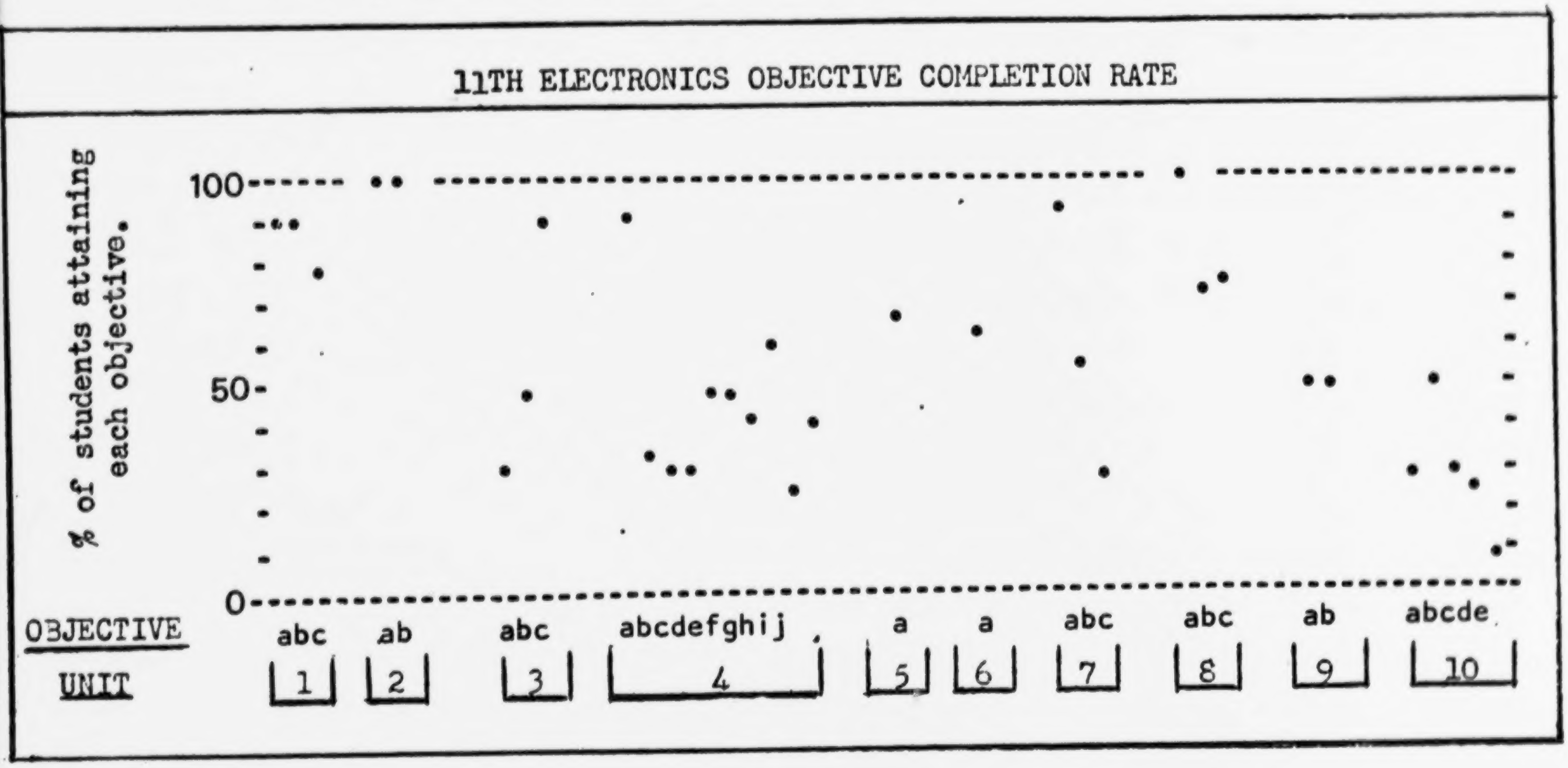

Figure 4.

Discussions with the students and a review of the materials indicate that some of the difficulties are a result of inadequate presentation of some concepts and/or the interdependence (e.g. failure of one item causes failure of another) of two or more test questions. Students not performing to established standards are referred to appropriate remedial activities. Additional testing is provided when the student feels he is ready to demonstrate an acceptable level of performance.

Completion time for most units was greater than expected. A part of the problem can be attributed to errors in draft materials and the type of operational problems typical of any developmental effort. With the refinement of the class operation, completion of training aids, improvement of printed materials, and revisions based on research data, training efficiency should show considerable improvement. There will always be, of course, those students who will learn or function at a slower rate than others.

Proposed Revisions

The evaluation failure rate (Figure 4), follow-up performance exam data, and student and instructor reactions, indicate certain areas requiring revision. Examples are units having too many objectives, inadequate presentation of difficult concepts, factual errors or contradictions in the materials. Text revision should eliminate such problems.

Because training aids play a major role in the program, their availability and reliability are essential. The printed circuit trainers have been quite satisfactory, but some changes including improved terminals will be instituted when new boards are fabricated. Various component assortments are also used and a packaging technique will be required to prevent loss, damage, or mixing. Assigning to students the issuance and maintenance of training aids should contribute to the continued high level of student responsibility. This will also permit the instructor more time for individual tutoring.

The most frequent complaint of the students is the level of external distractions. Visual distractions have been reduced with the installation of attractive translucent drapes which improve the area appearance, but prevent observation of out-of-doors activities. Distracting noise will be reduced with the improved soundproofing material now scheduled for installation. Lighting, equipment and aids, storage facilities, and the amount and type of work space, are quite adequate.

Postgraduation Follow-Up

Project ABLE is commited by contract to an evaluation of the programs based on performance after graduation. A controlled testing program will be necessary to meet such commitments. The evaluation will include performance check of the course objectives which were derived from a task analysis of the occupations for which training is provided. Project ABLE graduates will likely be compared on performance items to an appropriate population of persons not having had ABLE instruction. Other data such as employer's ratings, job satisfaction, student suggestions for program Improvement may be included.

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PLANS FOR NEXT QUARTER

The following activities are planned in the electronics area for the period ending 30 June 1969:

1. Continued implementation and evaluation of the first level general assembler and the second level electronics mechanic curricula.
2. Continued development of the third level radio-television repairman and electronics technician curricula with implementation planned for September 1969.
3. Planning for the revision of the general assembler and electronics mechanic curricula with revision to be completed by September 1969.
4. Planning for a non-graded electronics department which would allow horizontal and vertical transfer on the basis of student performance. Implementation planned for September 1969.
5. Planning for a cooperative work-study program to be part of the radio-television repairman and electronics technician programs. Development of frequency check list of behaviors appropriate to on-the-job training. Implementation planned for September 1969.
6. Planning for a flexible program of individualized scheduling in terms of: (1) academic support subjects appropriate to each student's needs, and (2) hours of assigned shop time on the basis of the student's career goals (and his course needs in other areas). Implementation planned for September 1969.

APPENDIX

A. OCCUPATIONAL FLOW CHARTS

B. JOB DESCRIPTIONS

C. TASKS

D. COURSE OBJECTIVES

E. GRADE 11 CURRICULUM OBJECTIVES

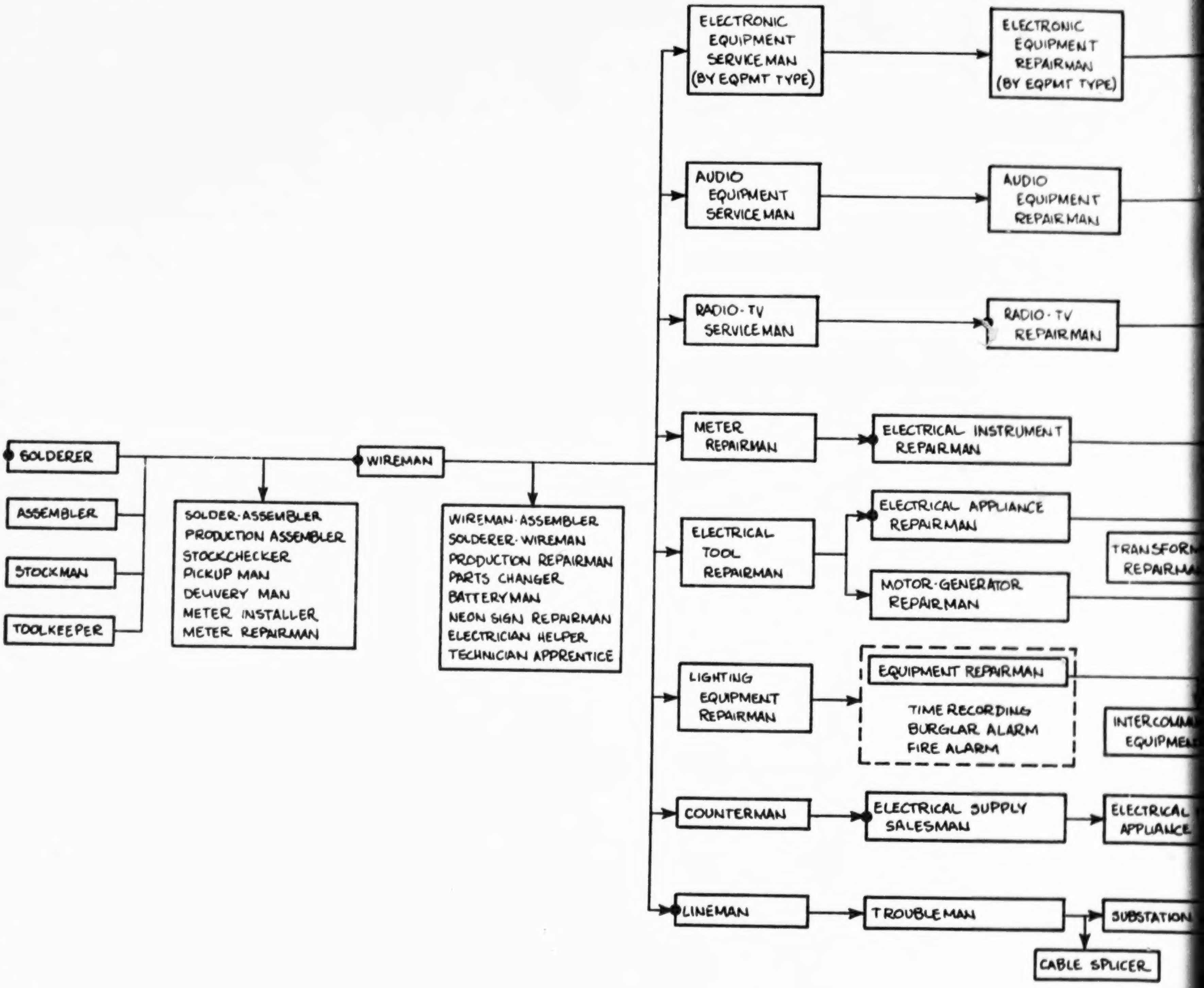
F. SAMPLE LEARNING UNITS

G. SAMPLE PERFORMANCE TEST

H. SAMPLE OCCUPATIONAL READINESS RECORD

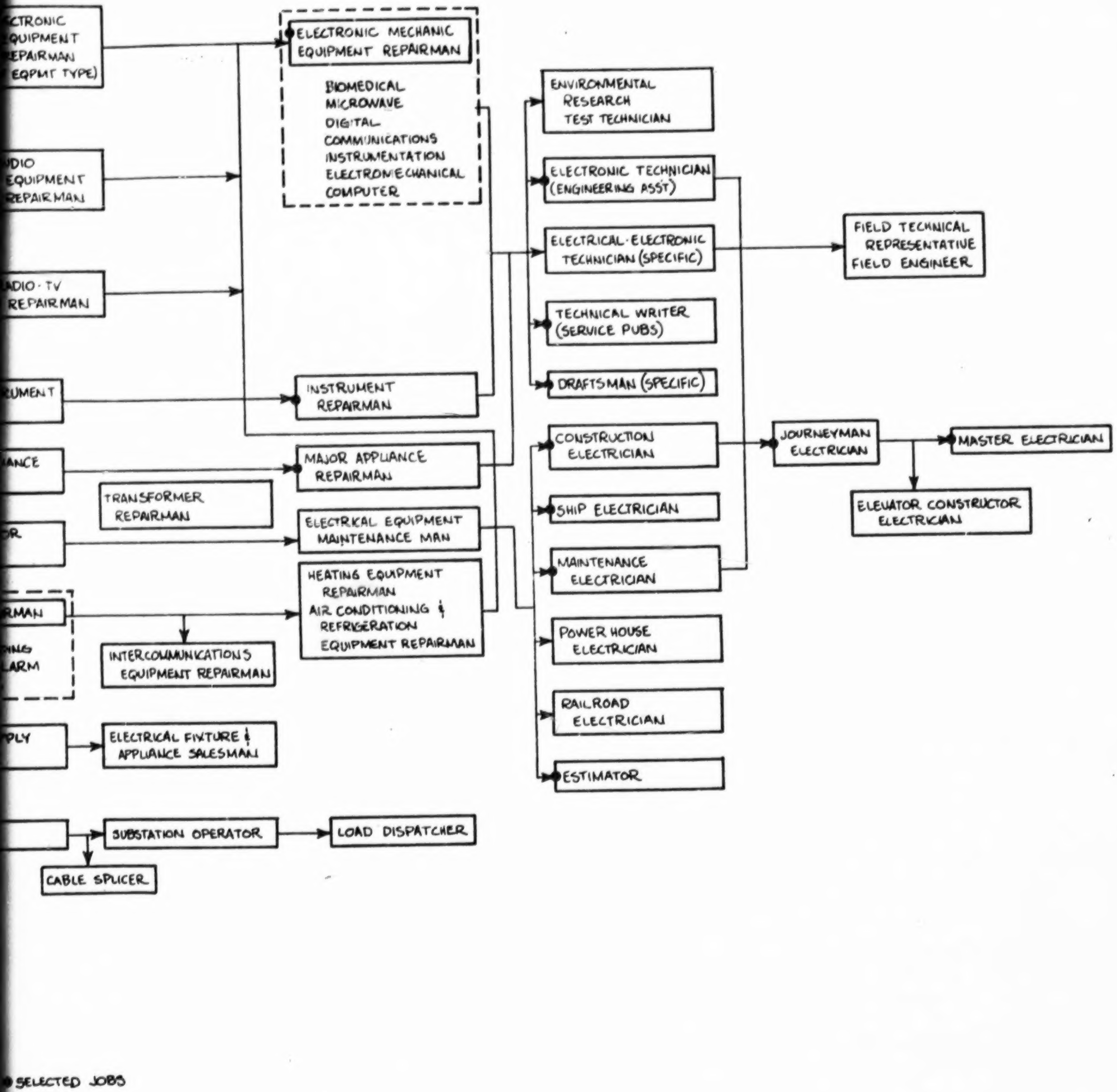
APPENDIX A
OCCUPATIONAL FLOW CHARTS

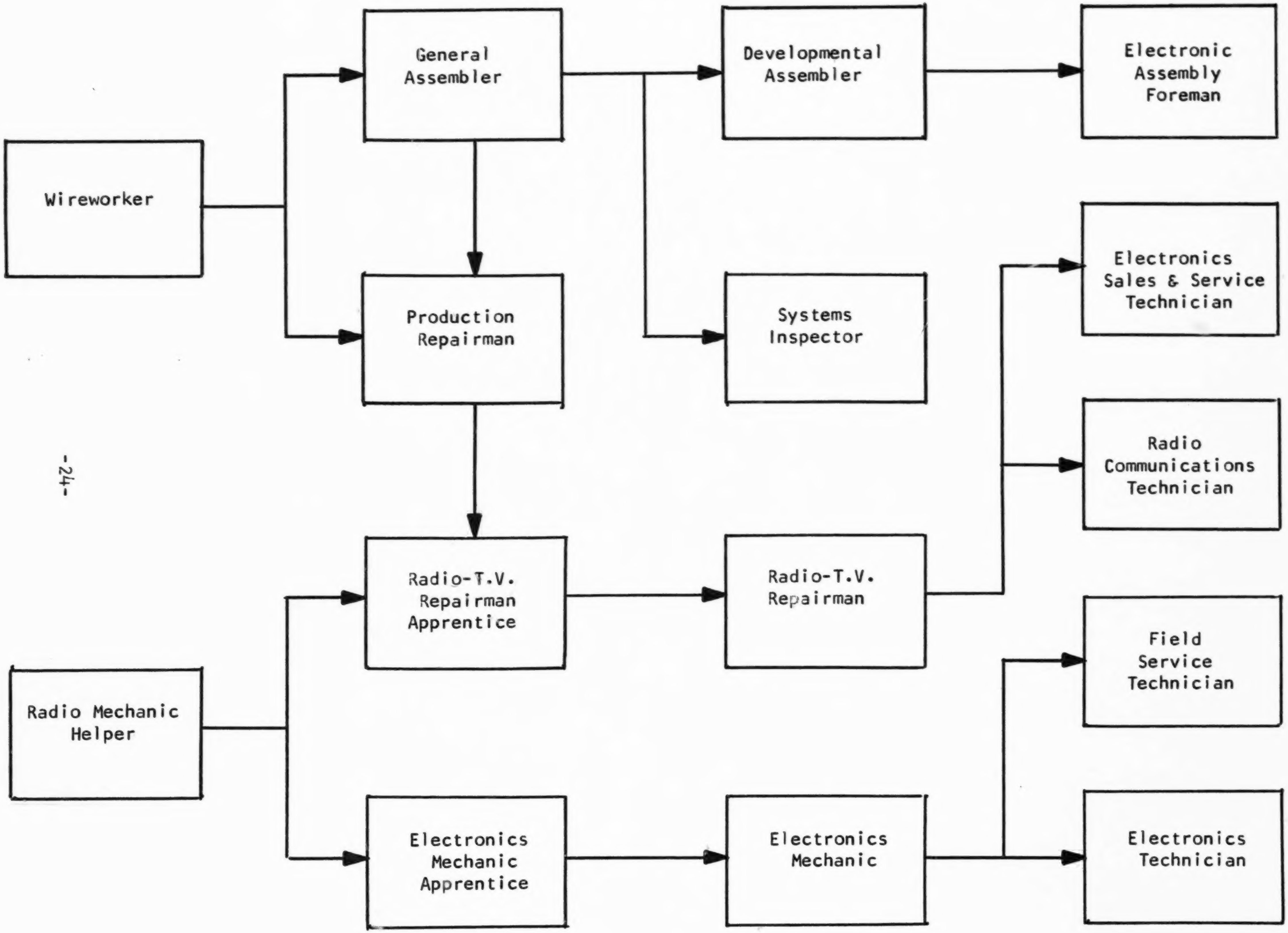
1. Original
2. Revised


SOLDERER
ASSEMBLER
STOCKMAN
TOOLKEEPER
SOLDER-ASSEMBLER
PRODUCTION ASSEMBLER
STOCKCHECKER
PICKUP MAN
DELIVERY MAN
METER INSTALLER
METER REPAIRMAN
WIREMAN
WIREMAN-ASSEMBLER
SOLDERER-WIREMAN
PRODUCTION REPAIRMAN
PARTS CHANGER
BATTERYMAN
NEON SIGN REPAIRMAN
ELECTRICIAN HELPER
TECHNICIAN APPRENTICE
ELECTRONIC EQUIPMENT SERVICEMAN (BY EQPMT TYPE)
ELECTRONIC EQUIPMENT REPAIRMAN (BY EQPMT TYPE)
AUDIO EQUIPMENT SERVICEMAN
AUDIO EQUIPMENT REPAIRMAN
RADIO-TV SERVICEMAN
RADIO-TV REPAIRMAN
METER REPAIRMAN
ELECTRICAL INSTRUMENT REPAIRMAN
ELECTRICAL TOOL REPAIRMAN
ELECTRICAL APPLIANCE REPAIRMAN
MOTOR-GENERATOR REPAIRMAN
TRANSFORM
REPAIRMA
LIGHTING EQUIPMENT REPAIRMAN
EQUIPMENT REPAIRMAN
TIME RECORDING
BURGLAR ALARM
FIRE ALARM
INTERCOMM
EQUIPME
COUNTERMAN
ELECTRICAL SUPPLY SALESMAN
ELECTRICAL
APPLIANCE
LINEMAN
TROUBLEMAN
SUBSTATION
CABLE SPLICER

ELECTRO-ELECTRONICS

● SELECTED JOBS


CTRONIC
QUIPMENT
EPAIRMAN
EQPMT TYPE)
UDIO
EQUIPMENT
REPAIRMAN
ADIO · TV
REPAIRMAN
RUMENT
IANCE
OR
RMAN
PING
LARM
PLY
ELECTRONIC MECHANIC EQUIPMENT REPAIRMAN
BIOMEDICAL
MICROWAVE
DIGITAL
COMMUNICATIONS
INSTRUMENTATION
ELECTROMECHANICAL
COMPUTER
INSTRUMENT REPAIRMAN
MAJOR APPLIANCE REPAIRMAN
TRANSFORMER REPAIRMAN
ELECTRICAL EQUIPMENT MAINTENANCE MAN
HEATING EQUIPMENT REPAIRMAN
AIR CONDITIONING & REFRIGERATION EQUIPMENT REPAIRMAN
INTERCOMMUNICATIONS EQUIPMENT REPAIRMAN
ELECTRICAL FIXTURE & APPLIANCE SALESMAN
SUBSTATION OPERATOR
LOAD DISPATCHER
CABLE SPLICER
ENVIRONMENTAL RESEARCH TEST TECHNICIAN
ELECTRONIC TECHNICIAN (ENGINEERING ASST)
ELECTRICAL-ELECTRONIC TECHNICIAN (SPECIFIC)
TECHNICAL WRITER (SERVICE PUBS)
DRAFTSMAN (SPECIFIC)
CONSTRUCTION ELECTRICIAN
SHIP ELECTRICIAN
MAINTENANCE ELECTRICIAN
POWER HOUSE ELECTRICIAN
RAILROAD ELECTRICIAN
ESTIMATOR
FIELD TECHNICAL REPRESENTATIVE FIELD ENGINEER
JOURNEYMAN ELECTRICIAN
MASTER ELECTRICIAN
ELEVATOR CONSTRUCTOR ELECTRICIAN
● SELECTED JOBS


Wireworker
General Assembler
Production Repairman
Developmental Assembler
Systems Inspector
Electronic Assembly Foreman
Radio Mechanic Helper
Radio-T.V. Repairman Apprentice
Electronics Mechanic Apprentice
Radio-T.V. Repairman
Electronics Mechanic
Electronics Sales & Service Technician
Radio Communications Technician
Field Service Technician
Electronics Technician

APPENDIX B

JOB DESCRIPTIONS

1. General Assembler
2. Electronics Mechanic

GENERAL ASSEMBLER

A. Defining the Population

The majority of general assemblers (electronics) are employed by end-product and component manufacturing firms. Most assemblers are considered to be semi-skilled workers, although a significant number are placed on the skilled level. At least six months training is required for workers employed in this area.

Excluded from this definition are:

1. Wireworkers whose primary concern is making wire harnesses and wiring installation.
2. Production repairmen whose primary mission is to locate and repair or replace defective components or wiring.
3. Developmental assemblers whose primary mission is to assist higher level personnel in developing new or prototype assemblies.

B. Statement of Mission

The primary missions of the general assembler are:

1. Install wiring and components in electronic assemblies.
2. Perform minor testing of completed electronic assemblies.

C. Segments

The main steps in the occupation of the general assembler are to identify what components and wiring are needed to complete the assembly, installing components and wiring and performing minor testing of completed assemblies.

D. Contingencies and Contexts

1. May have to substitute components with appropriate replacement parts.
2. May have to perform higher level test procedures.
3. May remove or replace defective components.

In some situations the general assembler may work on only one type of assembly while in smaller manufacturing establishments he may work on a variety of assemblies. In some situations, he will complete the assembly which was partially done by machines or other workers.

ELECTRONICS MECHANIC

A. Defining the Population

The majority of electronics mechanics are employed in repair shops in which all types of electronic equipment are repaired and in repair and service departments of large manufacturing companies. Included in this definition are those electronics mechanics employed by government agencies. Some of these jobs require federal or state licenses.

Excluded from this definition are:

1. Production repairmen who are primarily concerned with changing parts on specific equipments in a production repair.
2. Specialists who have been trained by either government agencies or private companies to service or repair specific pieces of equipment, systems, or sub-systems.

B. Statement of Mission

The primary missions of the electronics mechanic are:

1. Troubleshooting and repairing electronic equipment.
2. Servicing electronic equipment.

Other, secondary missions are:

1. Estimating repair costs.
2. Keeping maintenance and repair records.
3. Purchasing replacement parts.
4. Advising customers in purchase, operation, and maintenance of electronic equipment.
5. Installing equipment.

C. Segments

The main steps involved in the occupation of electronics mechanics are: diagnosis of electronic equipment service or repair requirements, location of equipment malfunction, and accomplishment of repair or service as required.

D. Contingencies and Contexts

1. May have to fabricate or substitute a replacement part when desired part is not available.

2. May have to instruct people in equipment operation or explain repair costs or estimates.

Job contexts are quite varied, ranging from a one-man repair shop to a large service department of a manufacturing company. The one-man repair shop may deal with many types of electronic equipment of varying complexities. This mechanic would necessarily perform tasks not generally considered as relating to the trade, such as clerical, secretarial, and custodial duties. On the other hand, electronics mechanics employed by large companies will generally be concerned with a specific set of tasks and work with highly specialized tools and equipment.

APPENDIX C

TASKS

1. General Assembler
2. Electronics Mechanic

GENERAL ASSEMBLER TASKS

1. Reads schematic diagrams
2. Selects components
3. Selects types of wires
4. Solders wires and components
5. Installs components (mechanical installation)
6. Makes wire harnesses (laces wires)
7. Selects hardware
8. Uses hand tools
9. Identifies test equipment
10. Performs continuity checks
11. Fabricates chassis
12. Identifies materials
13. Lays out assemblies
14. Makes visual and mechanical inspections
15. Replaces defective components or wiring
16. Winds coils

ELECTRONICS MECHANIC TASKS

1. Removes electronic components
2. Installs electronic components
3. Interprets drawings, sketches, schematics, and wiring diagrams
4. Measures voltage, resistance, current, frequency, and phase
5. Relates measured values to specified values to locate malfunctions
6. Tests components for conformity to specifications
7. Disassembles, repairs, and reassembles mechanical assemblies
8. Uses standard electronic hand tools
9. Selects parts by comparing circuit requirements with catalogs
10. Interprets schematic diagrams to determine circuit parameters and theoretical operation
11. Performs simple calculations to determine practicability of using substitute parts
12. Records in semi-permanent form, the results of tests, repair, and service
13. Visually inspects electronic circuits
14. Adjusts electronics components to cause circuit operation within specifications
15. Supervises and instructs other personnel in operating procedures, equipment, functions, and other technical subjects
16. Follows both verbal and written instructions
17. Selects instruments required for specific tests
18. Keeps parts inventory and repair records

APPENDIX D

COURSE OBJECTIVES

1. General Assembler
2. Electronics Mechanic

GENERAL ASSEMBLER - ELECTRONICS

COURSE OBJECTIVES

Task 1 Identify components.

C.O. Given a variety of components and component symbols, the student associates each component name and symbol with the appropriate component.

Task 2 Reads schematic diagrams.

C.O. Given a schematic diagram of an electronic assembly, the student interprets all symbols.

Task 3 Selects components.

C.O. Given a schematic diagram and various electronic components, the student selects components according to specifications in the schematic.

Task 4 Selects types of wires.

C.O. Given a schematic diagram of an electronic assembly and various types of wires, the student selects the appropriate wires according to their function.

Task 5 Solders wires and components.

C.O. Given an assembly requiring soldering, soldering gun or iron, and solder, the student solders the connections so that the joints are strong and have a shiny appearance.

Task 6 Installs components (mechanical installation)

C.O. Given a pictorial drawing, required components, hardware and hand-tools, the student installs the components in their proper position and tightens them so that they are secure.

Task 7 Makes wire harnesses (laces wires).

C.O. Given a wiring diagram, necessary wires and lacing, the student assembles the wires, laces the assembly and shapes it to specifications stated in the diagram.

Task 8 Selects hardware.

C.O. Given an assembly and various hardware, the student selects the appropriate hardware needed to mount components.

Task 9 Uses handtools.

C.O. Given various handtools, the student selects and uses the proper handtools for the job.

Task 10 Performs continuity checks.

C.O. Given a wired assembly, continuity tester and schematic diagram, the student performs continuity checks and compares results with specifications indicated on the schematic.

Task 11 Lays out assemblies.

C.O. Given a schematic, pictorial, components, layout tools, the student makes layout diagrams, lays out the assembly to conform with the diagrams and permits efficient assembly operations.

Task 12 Fabricates chassis.

C.O. Given layout diagram, chassis material, measuring tools, and hand and power tools, the student fabricates the chassis to conform with specifications indicated on the layout diagram.

Task 13 Makes visual and mechanical inspections.

C.O. Given a completed assembly, the student inspects all connections and other work visually and mechanically for any deficiencies (poor soldering, loose connections, short circuits, etc.)

Task 14 Replaces defective components or wiring.

C.O. Given an identified defective component or wire, its replacement, handtools, and soldering gun or iron, the student removes the defective component or wire and replaces it with its appropriate replacement item.

ELECTRONICS MECHANIC

COURSE OBJECTIVES

Task 1 Removes electronic components.

Task 2 Installs electronic components.

Task 3 Interprets drawings, sketches, schematics, and wiring diagrams.

C.O.1 Given a schematic, pictorial, layout, or wiring diagram, and the corresponding electronic or electro-mechanical equipment, worker can locate on the equipment any point, component, part, module, or unit specified by the schematic, pictorial, layout, or wiring diagram, and do so without error in a reasonable length of time as determined by the complexity of the equipment.

C.O.2 Given any electronic or electro-mechanical equipment, worker can sketch a layout, wiring, pictorial, or schematic diagram of any specified section of the equipment and do so without error in a reasonable length of time as determined by the complexity of the equipment.

Task 4 Measures voltage, resistance, current, frequency and phase.

C.O.1 Demonstrates competence in knowledge of characteristics and use of volt-ohmmeters, vacuum tube voltmeters, and oscilloscopes (as voltage measuring devices) by--

a. Selecting the appropriate instrument, stating the reasons for each selection.

b. Making the appropriate instrument settings and circuit connections, and obtaining the desired results within the maximum precision capability of the instrument selected.

The actual situations must involve DC, sinusoidal AC, and non-sinusoidal AC voltage measurements in both low and high impedance circuits.

C.O.2 Demonstrates competence in knowledge of characteristics and use of volt-ohmmeters, vacuum tube voltmeters, and Wheatstone bridge (as resistance measuring devices) by--

a. Selecting the appropriate instrument, stating the reasons for each selection.

b. Making the appropriate instrument settings and circuit connections, and obtaining the desired results within the maximum precision capability of the instrument selected.

C.0.3 Demonstrates competence in knowledge of characteristics and use of volt-ohmmeters, vacuum tube voltmeters, and watt-meters, (as applied to power measurements) by--

a. Selecting the appropriate instrument(s), stating the reason for each selection.

b. Making the appropriate instrument settings and circuit connections, and obtaining the desired results within the maximum precision capability of the instruments selected.

The actual situations should include both input and output power measurements of both DC and AC devices (both AF and RF).

C.0.4 Demonstrates competence in knowledge of characteristics and use of volt-ohmmeters, amprobes, and multi-range ammeters (as current measuring devices) by--

a. Selecting the appropriate instrument, stating the reasons for each selection.

b. Making the appropriate instrument settings and circuit connections, and obtaining the desired results within the maximum precision capability of the instrument selected.

C.0.5 Demonstrates competence in knowledge of characteristics and use of counters, oscilloscope-generator combinations, and frequency meters (as frequency determining devices) by--

a. Selecting the appropriate instrument, stating the reasons for each selection.

b. Making the appropriate instrument settings and circuit connections, and obtaining the desired results within the maximum precision capability of the instrument selected.

The frequencies involved must lie in the AF and the RF ranges.

C.0.6 Demonstrates competence in knowledge of characteristics and use of oscilloscopes and phase meters (as phase measuring devices) by--

a. Selecting the appropriate instrument, stating the reasons for each selection.

b. Making the appropriate instrument settings and circuit connections, and obtaining the desired results within the maximum precision capability of the instrument selected.

Task 5 Relates measured values to specified values to locate malfunctions.

C.O.1 Given the schematic diagram of any circuit found in one of the following groups, student can describe such parameters as approximate voltage amplitudes, input-output voltage waveforms, and voltage phase or time relationships found across the various components of the circuit.

a. Single phase and polyphase rectifier power supplies.
b. Voltage multipliers.
c. DC, AF, and RF amplifiers.
d. Sinusoidal and non-sinusoidal oscillators.
e. Detectors and demodulators.
f. Modulators.
g. Gates.
h. Triggering circuits.
i. Wave shaping circuits

C.O.2 Demonstrates competence in troubleshooting any piece of electronic or electro-mechanical equipment by combining appropriate procedures described in previous objectives.

Task 6 Tests components for conformity to specifications.

C.O. Demonstrates competence in testing components for conformity to specifications in the following manner. Given a component, student can determine theoretical specifications by reading the component's color code (if feasible) or referring to a specifications sheet or manual, determine an appropriate piece of test equipment or test procedure, set up the test in accordance with standard test methods, and obtain the actual values of the component. Students can then compare the actual values with the specified values and make a decision as to whether the component lies within specifications.

Task 7 Disassembles, repairs, and reassembles mechanical assemblies.

Task 8 Uses standard electronic hand tools.

Task 9 Selects parts by comparing circuit requirements with catalogs.

C.O. Given the schematic diagram of any electronic circuit with parts labeled, student can discern the parameters of any given component and, by consulting parts catalogs and specifications sheets, can specify by manufacturer and part number the actual parts and/or hardware from which the circuit can be built.

Task 10 Interprets schematic diagrams to determine circuit parameters and theoretical operation.

Task 11 Performs simple calculations to determine practicability of using substitute parts.

C.O. Demonstrates competence in performing simple engineering calculations to determine practicability of using substitute replacement parts when specified parts are unavailable.

Task 12 Records in semi-permanent form, the results of tests, repair, and service.

Task 13 Visually inspects electronic circuits.

Task 14 Adjusts electronics components to cause circuit operation within specifications.

C.O.1 Given a five-tube superheterodyne radio receiver and the availability of applicable test equipment, student can select appropriate test equipment and align the receiver in accordance with standard procedure and within the accuracy limits of the available equipment.

C.O.2 Given a communications receiver, student can select required test equipment and completely align and calibrate the receiver within the accuracy of the available equipment.

Task 15 Supervises and instructs other personnel in operating procedures, equipment, functions, and other technical subjects.

C.O. Given a specific repair job or equipment operation requirement in which the student has previously demonstrated an acceptable level of competence, student must demonstrate ability to instruct other personnel in operating procedures, equipment functions, and other technical subjects by training an incompetent student on the given repair job or operation to a degree where he can demonstrate competence according to the standards specified in the appropriate objective.

Task 16 Follows both verbal and written instructions.

Task 17 Selects instruments required for specific tests.

Task 18 Keeps parts inventory and repair records.

APPENDIX E

TOPIC OBJECTIVES

1. General Assembler
2. Electronics Mechanic

GENERAL ASSEMBLER - ELECTRONICS

TOPIC OBJECTIVES

Task 1 Identify components.

T.0.1 Given a variety of components, the student identifies each component.

T.0.2 Given a variety of components and component symbols, the student associates each symbol with the appropriate component.

Task 2 Read schematic diagrams

T.0.1 Given a schematic diagram of an electronic assembly, the student associates each symbol with the appropriate component (including values of each component).

Task 3 Selects components.

T.0.1 Given a schematic calling for various resistance values, the student identifies the appropriate components by color codes.

T.0.2 Given a schematic in which capacitance values are indicated, the student identifies the appropriate component by color codes and printed values.

T.0.3 Given a schematic which states transformer values, the student selects the proper transformer and identifies the values of leads by color codes.

T.0.4 Given a schematic in which components such as tubes, switches, transistors, diodes, etc., the student identifies each by its printed values.

Task 4 Selects types of wires.

T.0.1 Given a schematic diagram and various colored wires, the student associates each color with a function.

T.0.2 Given a schematic diagram and various colored wires, the student selects wires according to their function.

Task 5 Solders wires and components.

T.0.1 Given a situation requiring soldering of wires and/or components, the student selects the proper soldering iron or gun and solder to complete the operation without damaging the components or wiring.

T.0.2 Given a soldering iron or gun and solder, the student tins the soldering tips.

T.0.3 Given a situation requiring soldering, soldering gun or iron, solder, wire cutters and stripper, and long-nose pliers, the student strips off wire insulation (3/8"), tins the wire if necessary, makes a mechanical connection and solders the wire to the appropriate terminal. (The soldered joint must have a shiny appearance.)

Task 6 Installs components (mechanical installation)

T.0.1 Given a situation requiring installing of components, the student shows proper placement of components.

T.0.2 Given a situation requiring installation of components, the student selects the proper handtool needs for the installation.

T.0.3 Given a situation requiring installation of components the student associates proper hardware with the components to be installed.

Task 7 Makes wire harnesses (laces wires) •

T.0.1 Given any situation that requires a wire harness, the student demonstrates the proper methods used for gathering the wires at the start and end, and using the proper knot made from the proper lacing material.

Task 8 Selects hardware.

T.0.1 Given a bare chassis and a pictorial diagram or sample of finished products, the student demonstrates that he can select the proper size screw and nut (#4, #6, #8 or #10) and the correct length or size of all hardware, such as screws, nuts, lock washers, flat washers, grommets, cable clamps, ground lugs, shoulder washers, spacers, and terminal board feet, etc.

Task 9 Uses handtools.

T.0.1 Given various handtools the student identifies each by appearance and function.

T.0.2 Given a bare chassis and a sample of the finished product, the student demonstrates that he can use the proper tool in mounting components such as tube sockets, BNC's, standoffs, switches, and etc.

Task 10 Performs continuity checks.

(Course objectives only)

Task 11 Layout assemblies.

T.0.1 Given a schematic, components and layout tools, the student must select the size and type of chassis that would be best for the job, and must show dimensions on a layout diagram, which includes the size of transformers, screws, and tube sockets, for example 5/8" for 7-pin miniature, 3/4" for 9-pin miniature, etc.

T.O.2 Given a schematic, components, and layout tools, the student must layout the components in a loose arrangement on a breadboard, keeping in mind short leads, and short ground leads, which means properly orienting the components and wires to avoid criss-crossing.

Task 12 Fabricates chassis.

T.O.1 Given a layout diagram, schematic and chassis materials, the student associates fabrication procedure with type of chassis to be fabricated.

T.O.2 Given a layout diagram, schematic and chassis materials, the student executes the selected procedure in fabricating a given chassis (metal, perf. board or printed circuit).

Task 13 Makes visual and mechanical inspections.

T.O.1 Given a completed assembly, the student inspects all electrical and mechanical connections by referring to a standard model or schematic, and rejects all assemblies that do not meet the standard because of poor soldering, loose connections, missing hardware, improper hardware, short circuits, poor eye appeal, etc.

Task 14 Replaces defective components or wiring.

T.O.1 Given an identified defective component or wires and its replacement, the student demonstrates care in removing the defective component and replaces it to meet commercial and military standards.

Quincy Vocational-Technical School Electro-Electronics Department
Project ABLE

ELECTRONICS MECHANIC PROGRAM

Learning Units and Objectives

1. VOM Ohmmeter

   a. Measure resistance, using the VOM multimeter. Must be within the indicated tolerance.

   b. Determine the ohmic value of resistors, using the color code. Values must be exact and must include tolerance expressed as a percentage.

   c. Calculate the minimum and maximum acceptable values of a resistor, using the color code. Values must be exact.

2. Soldering Techniques

   a. Solder an electrical component to a printed circuit board, using a soldering iron, long-nose pliers, and solder. Component must be rigidly soldered and pass a continuity check.

   b. Solder a solid-state diode to a printed circuit board, using a soldering iron, long-nose pliers, solder, and heat sink. Diode must be rigidly soldered and pass a continuity check.

3. Using Ohm's Law

   a. Measure DC voltage, using the VOM multimeter. Reading must be within two graduations of the correct value.

   b. Measure DC current, using the VOM multimeter. Reading must be within two graduations of the correct value.

   c. State the change in E, I, or R when one is changed, using Ohms Law, 100% accuracy required.

4. DC Circuits

   a. Identify series, parallel, and series-parallel circuits from schematics. 100% accuracy required.

   b. Measure DC voltage in a series circuit, using the VOM multimeter. Reading must be within two graduations of the correct value.

   c. Measure DC voltage in a parallel circuit, using the VOM multimeter. Reading must be within two graduations of the correct value.

   d. Measure DC voltage in a series-parallel circuit, using the VOM multimeter. Reading must be within two graduations of the correct value.

   e. Measure DC current in a series circuit, using the VOM multimeter. Reading must be within two graduations of the correct value.

   f. Measure DC current in a parallel circuit, using the VOM multimeter. Reading must be within two graduations of the correct value.

   g. Measure DC current in a series-parallel circuit, using the VOM multimeter. Reading must be within two graduations of the correct value.

   h. Measure single, multiple, or total resistance values in a series circuit, using the VOM multimeter. Reading must be within the indicated tolerance.

   i. Measure individual, branch, or total resistance values in a parallel network, using the VOM multimeter. Reading must be within the indicated tolerance.

   j. Measure individual, branch or total resistance values in a series-parallel circuit, using the VOM multimeter. Reading must be within the indicated tolerance.

5. VOM - AC Voltmeter

   a. Measure AC voltages using the VOM multimeter. Reading must be within two graduations of the exact value.

6. Troubleshooting (Shorts and Opens)

   a. Locate the malfunctioning component and identify the probable cause, given a schematic, malfunction sympton, and using the VOM multimeter. 100% accuracy required.

7. Vacuum Tube Voltmeter - VTVM

   a. Measure resistance, using the VTVM. Reading must be within the indicated tolerance.

   b. Measure DC voltage, using the VTVM. Reading must be within two graduations of the correct value.

   c. Measure AC voltage,using the VTVM. Reading must be within two graduations of the correct value.

8. Solid-State Diodes

   a. Identify the anode and the cathode of a solid-state diode, using an ohmmeter, 100% accuracy required.

   b. Determine the condition of a solid-state diode by performing a forward-reverse resistance check, using an ohmmeter, 100% accuracy required.

   c. Determine diode biasing, using a schematic, 100% accuracy required.

9. Voltage Dividers

   a. Determine the potential difference between, and the polarity of, two points in a DC circuit (not including ground), using a voltmeter. Reading must be within two graduations of the correct value.

   b. Measure positive and negative DC voltage with respect to ground, using a voltmeter. Reading must be within two graduations of the correct value.

10. Bridge Circuits

   a. Calculate the potential difference between the open terminals of a bridge circuit, using Ohm's Law. Must have exact value.

   b. Determine the potential difference between, and the polarity of, the open terminals of a bridge circuit using a VOM or VTVM. Answer must be within ± two graduations of correct value and the condition expressed as balanced or unbalanced, 100% accuracy required.

   c. Calculate the amount and direction of current flow through the galvanometer of a wheatstone bridge using a schematic diagram. Answer must be exact and direction indicated as right to left or left to right, 100% accuracy required.

   d. Determine the amount and direction of current flow through the galvanometer of a wheatstone bridge using a galvanometer. Answer must be within ± two graduations of the correct value and direction indicated as right to left or left to right, 100% accuracy required.

   e. Calculate the voltage across the current through the fifth resistor in a five resistor bridge circuit using Thevenin's Theorem. Answer must be exact.

11. Basic Oscilloscope Operation

   a. Identify the common, horizontal, and vertical controls of an oscilloscope, using a pictorial diagram. 100% accuracy required.

   b. Measure potential difference, using the oscilloscope. Reading must be within ± 10% of the correct value.

   c. Determine the polarity relationship between two points of a DC series circuit (not including ground) using the oscilloscope. 100% accuracy required.

12. Testing Solid-State Diodes (DC)

   a. Determine the condition of solid-state diodes, using the diode tester, oscilloscope, and trace patterns. Answer will be expressed as Good or Bad.

13. Temperature Coefficient

    a. Select the definition of temperature coefficient from a list of four. 100% accuracy required.

    b. Determine the change in circuit current when a diode (with negative temperature coefficient) is subjected to heat, using an ammeter and a soldering iron. Answer will be expressed as increase or decrease.

14. Basic Troubleshooting Techniques

    a. Locate the malfunctioning component and identify the probable cause, given a schematic, malfunction symptom, and using available test equipment. 100% accuracy required.

15. Testing Transistors - VOM Multimeter

    a. Determine the type of transistor, (NPN or PNP) using an ohmmeter. 100% accuracy required.

    b. Determine the apparent condition of transistors, using an ohmmeter. Answer will be expressed as Good or Bad.

    c. Determine the conducting state of a transistor, using the shorting method. After shorting, the condition will be identified as on or off.

    d. Determine the conducting state of a transistor, using a voltmeter. Answer will be expressed as on or off.

16. Transistor Control

    a. Determine the effect of increased light on the output voltage of a photovoltaic cell, using the available test equipment and flashlight. Answer will be expressed as increase or decrease.

    b. Determine the effect of a change in bias on the output voltage of a transistor, using available test equipment. Answer will be expressed as increase or decrease.

17. Testing Transistors, Oscilloscope-DC

    a. Determine the condition of a transistor using the oscilloscope, transistor tester, and trace patterns. Answer will be expressed as good or bad.

18. Printed Circuits

    a. Identify the precautions used against heat on printed circuits. 100% accuracy required.

    b. Identify the preliminary troubleshooting steps for printed circuits. 100% accuracy required.

19. Alternating Current

    a. Identify the various characteristics of an AC waveform, using a list of terms and a pictorial diagram. 100% accuracy required.

    b. Measure peak to peak voltage, using the oscilloscope. Reading must be within ± 10% of correct value.

    c. Calculate the effective value of an AC waveform (voltage or current) using the formula for E effective. Answer must be exact to 2 decimal places.

    d. Determine the DC reference of an AC voltage, using the oscilloscope. Answer must be within ± 10% of exact value.

    e. Determine voltage, current and resistance, using Ohm's Law relationships or available test equipment. Answer must be within ± 10% of exact value when test equipment is used. Calculations must be exact.

    f. Identify the phase relationship between E_A and E_R of a resistive circuit using the oscilloscope. Answer will be in terms of IN or OUT of phase.

20. Measuring Waveforms

a. Determine the frequency of an AC signal, using the oscilloscope. Answer must be within ± 10% of exact value.

b. Determine the frequency of a square wave using the oscilloscope. Answer will be within ± 10% of exact value.

21. Testing Solid-State Devices, Oscilloscope-AC

a. Determine the condition of solid-state diodes, using the oscilloscope. Answer will be expressed as good or bad.

b. Determine the condition of transistor, using the oscilloscope. Answer will be expressed as good or bad.

22. Reactive Components

a. Determine the effect of change in inductance on current, using a series RL circuit, a variable inductor, and a-c ammeter. Answer in terms of increase or decrease with given inductance change.

b. Determine the effect of change in frequency on current, using a series RL circuit and a-c ammeter. Answer in terms of increase or decrease for a given frequency change.

c. Find inductive reactance (X_L) with given values of f and L using a series RL circuit, VTVM, and a-c ammeter. Answer must be within ± 10% of actual value.

d. Determine the phase relationship of circuit current with respect to applied voltage using a series RL circuit and oscilloscope. Answer in terms of lead or lag.

e. Find impedance (Z) of a given RL circuit, using a VTVM and a-c ammeter. Answer must be within ± 10% of actual value.

22. Reactive Components (Continued)

f. Determine the effect of change in capacitance on current, using a series RC circuit, variable capacitor, and a-c ammeter. Answer in terms of increase or decrease with a given capacitance change.

g. Determine the effect of change in frequency on current, using a series RC circuit and a-c ammeter. Answer in terms of increase or decrease for a given frequency change.

h. Find capacitive reactance (X_C) with given values of f and C using a series RC circuit, VTVM, and a-c ammeter. Answer must be within ± 10% of actual value.

i. Determine the phase relationship of circuit current with respect to applied voltage using a series RC circuit and oscilloscope. Answer in terms of lead or lag.

j. Find impedance (Z) of a given RC circuit, using a VTVM and a-c ammeter. Answer must be within ± 10% of actual value.

k. Determine the effect on current, when capacitance is added in parallel using a parallel circuit, variable capacitor, and a-c ammeter. Answer will be in terms of increase, decrease, or remain the same.

l. Determine the effect on current, when inductance is added in parallel using a parallel circuit, variable inductor, and an a-c ammeter. Answer will be in terms of increase, decrease, or remain the same.

23. Series Reactive Circuits

a. Determine the resonant frequency using a series RCL circuit, variable frequency source and a-c ammeter. Answer must be within ± 10% of the actual value.

b. Tune an inductor and capacitor (LC) for resonance using a series RCL circuit, given frequency and a-c ammeter. Inductor value must be accurate to within 1 henry and capacitor value to within .01 microfarad.

c. Determine the phase relationship of current with respect to applied voltage in a series RCL circuit, using the oscilloscope. Answer will be in terms of lead or lag.

2

23. Series Reactive Circuits (Continued)

d. Measure E_L and E_C to find circuit condition, (above, below, or at resonance) using a series RCL circuit and VTVM. Answer will be in terms of inductive, capacitive, or resonant.

24. Parallel Reactive Circuits

a. Calculate the impedance of a parallel RL circuit, using measured values of E_A and I (line). Answers must be within ± 10% of actual value.

b. Determine the effect of a change in frequency on the line current in a parallel RL circuit, using an a-c ammeter. Answer will be expressed as increase or decrease.

c. Determine the effect of a change in inductance on the line current in a parallel RL circuit, using an a-c ammeter. Answer will be expressed as increase or decrease.

d. Determine the effect of a change in capacitance on the line current in a parallel RC circuit, using an a-c ammeter. Answer will be expressed as increase or decrease.

e. Determine the effect of a change in frequency on the line current in a parallel RC circuit, using an a-c ammeter. Answer will be expressed as increase or decrease.

f. Calculate the impedance of a parallel RC circuit, using measured values of E_A and I (line). Answer must be within ± 10% of the actual value.

g. Determine the effect of frequencies above, below and at resonance on line current of a parallel RCL circuit, using an a-c ammeter. Answer must be expressed as increase or decrease.

25. Resonance

a. Determine the "bandwidth" and "bandpass frequencies" of a series RCL circuit, using a VTVM. The value of bandwidth must be accurate to within ± 10%.

25. Resonance (Continued)

   b. Determine the "bandwidth" and "bandpass frequencies" of a parallel RCL circuit, using a VTVM. The value of bandwidth must be accurate to within ± 10%.

   c. Identify the tank circuit branch with the greater current when a frequency above or below resonance is applied, using an a-c ammeter. Circuit must be identified as inductive or capacitive.

26. Power Supplies and Filters

   a. Identify the components of a full wave recitfier, from a schematic. 100% accuracy required.

   b. Obtain the output wavershape of a full wave recitfier using the oscilloscope. Selects from a list of four waveshapes the one which most closely resembles the oscilloscope display.

   c. Identify Pi, capacitive, inductive, and "T" type filters from a schematic. 100% accuracy required.

   d. Locate the malfunctioning component in a full wave rectifier and identify the probable cause, using the available test equipment. 100% accuracy required.

27. Voltage Doublers

   a. Obtain the output waveshape of a voltage doubler, using the oscilloscope. Select from a list of four waveshapes the one which most closely resembles the oscilloscope display.

   b. Locate the malfunctioning component in a voltage doubler, using the available test equipment. 100% accuracy required.

28. Bridge Rectifiers

   a. Identify the components and their function in a bridge rectifier, using a schematic. 100% accuracy required.

   b. Obtain the output waveshape of a bridge rectifier using the oscilloscope. Select, from a list of waveshapes, the one which most closely resembles the oscilloscope display.

28. Bridge Rectifiers (Continued)

c. Locate the malfunctioning component in a bridge rectifier, using the available test equipment. 100% accuracy required.

29. Zener Diodes

a. Identify zener diode symbols, from a schematic diagram. 100% accuracy required.

b. Identify the voltage regulator tube symbol, from a schematic diagram. 100% accuracy required.

c. Obtain the waveshape across a zener diode, using the oscilloscope. Select from a list of four waveshapes the one which most closely resembles the oscilloscope display.

30. Regulated Power Supplies

a. State the effect of a change in input voltage on the output voltage of a regulated DC power supply using a schematic. Answer will be expressed as increase, decrease or remain the same.

b. State the effect of a change in load resistance on the output voltage of a regulated DC power supply using a schematic. Answer will be expressed as increase, decrease, or remain the same.

31. Basic Amplifier Circuits

a. Identify the three basic amplifier configurations from schematics. 100% accuracy required.

b. Select the characteristics of a common base amplifier from a given list. 100% accuracy required.

c. Select the characteristics of a common emitter amplifier from a given list. 100% accuracy required.

d. Select the characteristics of a common collector amplifier from a given list. 100% accuracy required.

32. Audio Amplifier

a. Select the characteristics of an audio amplifier from a given list. 100% accuracy required.

b. Identify the various types of amplifier coupling from schematic. 100% accuracy required.

c. Determine if the RC coupling in an audio amplifier is adequate, using the oscilloscope. Answer will be expressed as good or bad.

d. Locate the malfunctioning component of an audio amplifier, and identify the probable cause, using the available test equipment. 100% accuracy required.

33. Push-pull Amplifiers

a. Select the characteristics of a push-pull amplifier from a given list. 100% accuracy required.

b. Identify the malfunctioning component of a push-pull amplifier from a given schematic and symptoms. 100% accuracy required.

34. Video Amplifier

a. Select the characteristics of a video amplifier from a given list. 100% accuracy required.

b. Identify the components that provide low frequency compensation on a schematic. 100% accuracy required.

c. Identify the components that provide high frequency compensation in a video amplifier on a schematic. 100% accuracy required.

35. Vacuum Tubes

a. Determine the condition of vacuum tubes, using the tube tester. Answer will be expressed as good or bad.

b. Identify the elements of vacuum tubes from schematic symbols. 100% accuracy required.

c. Identify multi-unit tubes from schematic symbols. 100% accuracy required.

d. Number tube and socket pins using pictorial diagrams. 100% accuracy required.

e. Identify gas filled tubes from schematic symbols. 100% accuracy required.

36. Oscillator Principles

a. Identify the major parts of an oscillator, on a given block diagram. 100% accuracy required.

37. Crystal Oscillators

a. Select, from a list of statements, the one which correctly identifies the path of current flow through a crystal oscillator. 100% accuracy required.

38. Hartley Oscillator

a. Identify the path of current flow through a Hartley oscillator, using a schematic. Select from a list of four statements the one which correctly identifies the current path.

b. Obtain the output waveshape of a Hartley oscillator, using the oscilloscope. Select from a list of four waveshapes the one which most closely resembles the oscilloscope display.

39. Blocking Oscillator

a. Identify the path of current through a blocking oscillator, using a schematic. Select from a list of four statements the one which correctly identifies the current flow.

b. Obtain the output waveshape of a Blocking oscillator using the oscilloscope. Select from a list of waveshapes, the one which most closely resembles the oscilloscope display.

40. Multivibrators

a. Identify the components controlling the frequency of the astable multivibrator from an actual circuit. 100% accuracy required.

b. Find the frequency of an astable multivibrator using the oscilloscope and the formula f = 1/t. Answer must be within ± 50 cps of the actual frequency.

c. Synchronize an astable multivibrator using an external source. The multivibrator must be stable at the source frequency as observed on the oscilloscope.

d. Select characteristics of the astable multivibrator from a listing. 100% accuracy required.

e. Obtain the output of a monostable multivibrator using an oscilloscope. Select from a list of illustrations the one which most closely resembles the oscilloscope display.

f. Obtain the output of a Bistable multivibrator using an oscilloscope. Select from a list of illustrations the one which most closely resembles the oscilloscope display.

g. Select the application of a Bistable multivibrator when externally triggered from a listing. 100% accuracy required.

41. Troubleshooting Multivibrators

a. Locate the malfunctioning component in a Bistable multivibrator and identify the probable cause using the available test equipment. 100% accuracy required.

b. Locate the malfunctioning component in a monostable multivibrator and identify the probable cause (using the probable cause) using the available test equipment. 100% accuracy required.

c. Locate the malfunctioning component in an astable multivibrator and identify the probable cause using the available test equipment. 100% accuracy required.

42. Differentiation and Integration

a. Determine the type of time constant in an RC or RL circuit given R, C or L and the period of the input. Answer will be expressed as long, medium, or short.

b. Obtain the output of a differentiating circuit using the oscilloscope. Select from a list of waveshapes the one which most closely resembles the oscilloscope display and the type of time constant associated with it. 100% accuracy required.

c. Obtain the output of an integrating circuit, using the oscilloscope. Select from a list of waveshapes the one which most closely resembles the oscilloscope display and the type of time constant associated with it. 100% accuracy required.

43. Gating Circuits

a. Determine whether or not a gating circuit will accept a negative trigger pulse, using a VOM and negative pulse generator. Answer will be expressed as yes or no.

b. Determine the type of gate that will operate a given circuit, using a schematic. Answer will be expressed as OR and AND.

c. Determine the type of gate that will operate a given circuit, using a schematic. Answer will be expressed as NOR or NAND.

44. Binary Counting

a. Convert numbers in the binary system to their equivalent in the decimal system. Must have exact value.

b. Determine what binary digits will give a specific decimal value. Must pass instructor check.

45. Electromagnetism and Relays

a. Match terms of electromagnetism to their correct definitions. 100% accuracy required.

b. Label the major parts of a relay on a given pictorial diagram. 100% accuracy required.

c. Identify the malfunctioning component in a relay circuit and the probable cause, using the available test equipment. 100% accuracy required.

46. Motors

a. Select the characteristics of motors, from a given schematic. 100% accuracy required.

b. Identify series, shunt, and compound wound motors, from given schematics. 100% accuracy required.

c. Select the characteristics of bi-directional DC motors, from a given list. 100% accuracy required.

47. Servo Principles and Synchros

a. Adjust a transmitter synchro (1/3) to electrical zero using a VOM multimeter. Maximum allowable voltage from S_1 to S_3 is 5 volts.

b. Adjust a control transformer (1/3) to electrical zero using a VOM multimeter. Maximum allowable voltage from R_1 to R_2 is 5 volts.

c. Identify basic units of a servo system from a block diagram. 100% accuracy required.

48. Analog Computers

a. Select the functional characteristics of an analog computer from a given list. 100% accuracy required.

49. Magnetic Amplifiers and Saturable Reactors

a. Select the operating characteristics of a saturable reactor from a given list. 100% accuracy required.

b. Select the operating characteristics of a magnetic amplifier from a given list. 100% accuracy required.

50. Silicon Controlled Recifiers

a. Identify the symbol for a silicon controlled rectifier within a given circuit schematic. 100% accuracy required.

b. Label the elements of a silicon controlled rectifier on a given schematic. 100% accuracy required.

c. Select the functional characteristics of a SCR from a given list. 100% accuracy required.

51. Unijunction Transistor (UJT)

   a. Identify the symbol for a unijunction transistor within a given circuit schematic. 100% accuracy required.

   b. Select the functional characteristics of a unijunction circuit from a given list. 100% accuracy required.

   c. Obtain the output waveshape of a unijunction transistor circuit using the oscilloscope. Select from a list of waveshapes the one which most closely resembles the oscilloscope display.

52. Sweep Generators

   a. Identify the current path in a basic sweep generator circuit using a schematic 100% accuracy required.

   b. Determine the effect of changing the sweep capacitor size on the output amplitude of a sweep generator using the oscilloscope. Answer will be expressed as an increase or decrease.

   c. Determine the effect of changing the input frequency on the output linearity of a sweep generator using the oscilloscope. Answer will be expressed as an increase or decrease.

53. Limiters, Clampers and Choppers

   a. Match the output waveshapes of limiters, clampers, and choppers with the appropriate circuit, from a given list of waveshapes and a list of circuits. 100% accuracy required.

   b. Obtain the output waveshape of a limiter, using the oscilloscope. Select the waveshape which most closely resembles the oscilloscope display. 100% accuracy required.

   c. Obtain the output waveshape of a clamper using the oscilloscope. Select the waveshape which most closely resembles the oscilloscope display. 100% accuracy required.

53. Limiters, Clampers and Choppers (Continued)

d. Select the characteristics of an ac chopper from a given list. 100% accuracy required.

54. Photosensitive Devices

a. Identify the symbol for a photovoltaic cell and a photovoltaic cell and a photoresistor from a given list. 100% accuracy required.

b. Select the characteristics of a photovoltaic cell from a given list. 100% accuracy required.

c. Select the characteristics of a photoresistor from a given list. 100% accuracy required.

d. Determine the voltage across a photovoltaic cell at maximum light using a VOM and a flashlight. Answer must be within ± 10% of correct value.

e. Calculate the resistance of a photoresistor receiving maximum light, from measured values of voltage across and current through the photoresistor, using a flashlight and a VOM. Answer must be within ± 10% of correct value.

APPENDIX F

SAMPLE LEARNING UNITS

1. General Assembler -
   Common Electronic Components
2. Electronics Mechanic -
   Troubleshooting Shorts and Opens
3. Electronics Mechanic -
   Resonance

UNIT - COMMON ELECTRONIC COMPONENTS

(E) DIODES, RECTIFIERS, TRANSISTORS, and POWER RECTIFIERS

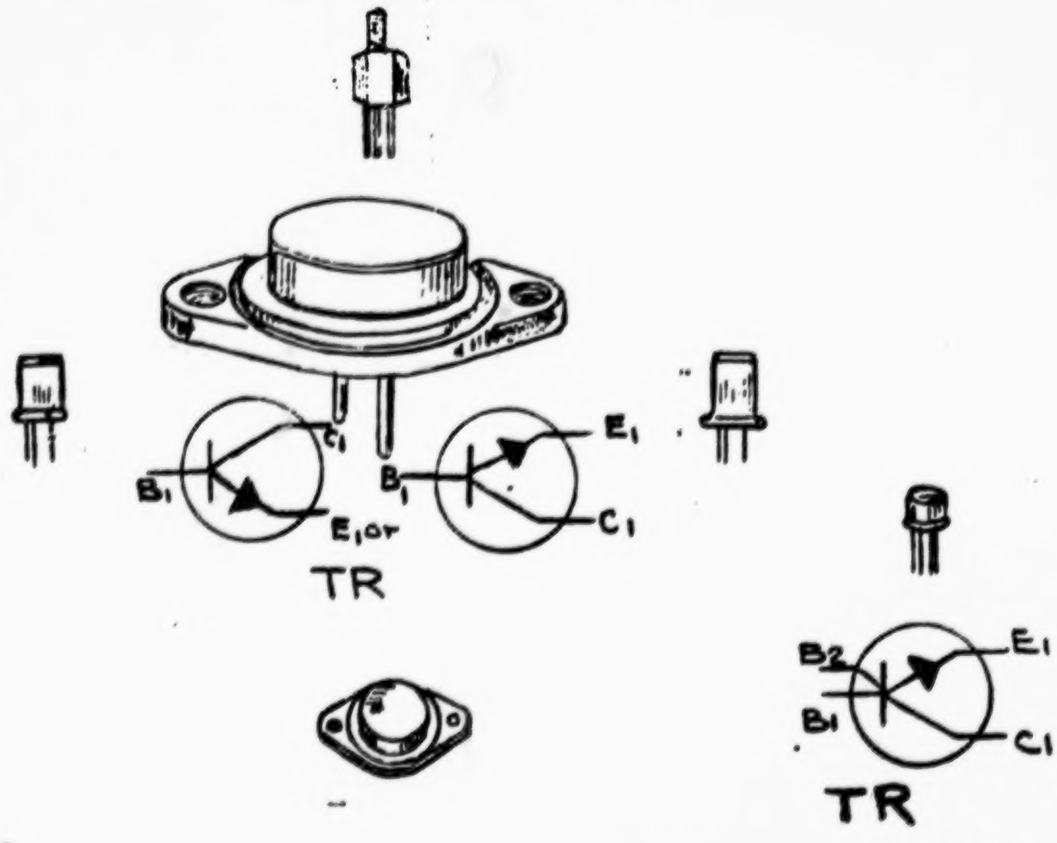
OBJECTIVE E: From a group of electronic components, pick out and name each kind: DIODES, RECTIFIERS, POWER RECTIFIERS, and TRANSISTORS.

Learning Aids: None

Equipment: Examples of components listed above.

Overview: Small components such as solid state devices were highly responsible for putting man into space. A general assembler must know the different kinds and what they look like before he can assemble the equipment requiring them.

At the end of this section you will be expected to list the correct names of 10 examples of components studied.



____ DIODE

____ POWER RECTIFIER

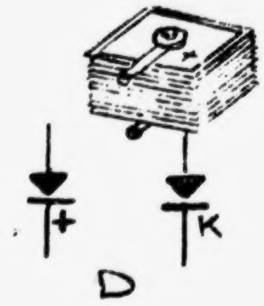
____ RECTIFIER

____ TRANSISTOR

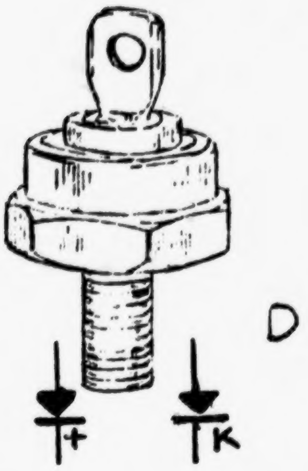
1. ____

Learning Activities:

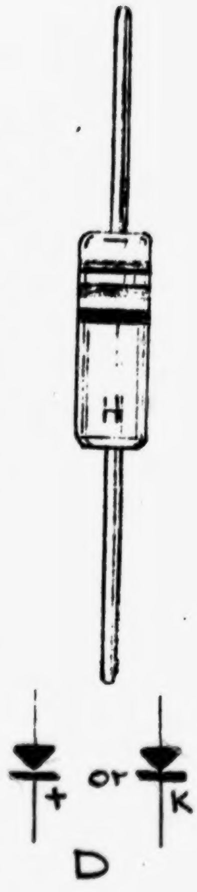
1. (a) SEMICONDUCTORS, sometimes called SOLID STATE DEVICES may be DIODES, RECTIFIERS or TRANSISTORS. Try to guess the name of each solid state device by writing the number of the picture beside its correct name.



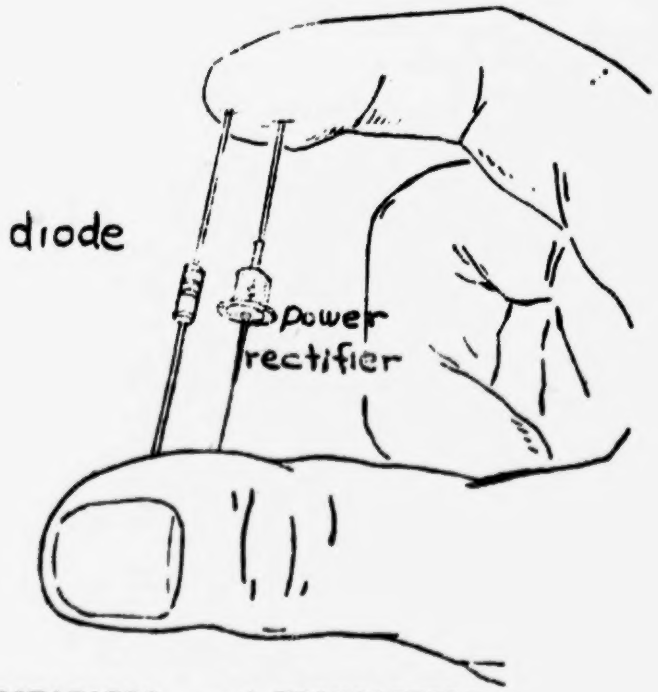
4. ____________________



2. ____________________



3. ____________________

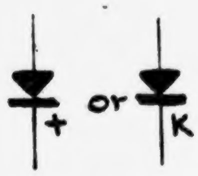


(b) Get the boxes marked DIODES, RECTIFIERS, and TRANSISTORS. Look at the labels on the components in the boxes. Check to see if you were correct.

(c) Label each component on this page correctly. Use the boxes to help you.

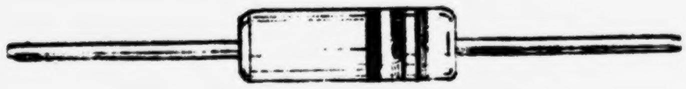
2. (a) Take out the DIODES. Some diodes do the same job as a simple vacuum tube. They change the AC current to DC current making it possible to have appliances with DC current in your home.

(b) From the box find examples of DIODES shown on the previous page. Do you notice a symbol printed on most of the diodes? It looks like this.

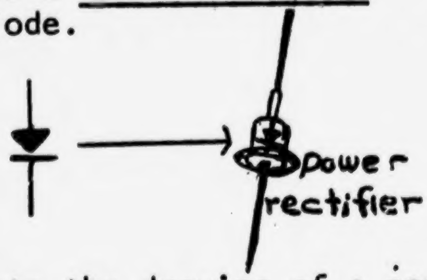


Diodes are usually very small.

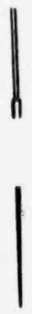
(c) Draw the symbol on this diode.



3. (a) Take out the RECTIFIERS. Rectifiers change AC to DC in the power supplies of radio and T.V. receivers. The simplest solid state device is the POWER RECTIFIER. Can you find the rectifier that looks like a top hat? This is a POWER RECTIFIER. It has the same symbol as the diode.



(b) Complete the drawing of a power rectifier. See the drawing in Activity 1 (a).



4. (a) Take out the TRANSISTORS. Transistors are modern devices doing the same job as the vacuum tube. They are smaller, last longer and are more economical to operate than the vacuum tube. If it weren't for the transistor you would be carrying a bulky portable radio instead of a compact transistor radio whenever you wanted to listen to your favorite station at the beach.

(b) How many terminals do TRANSISTORS have? They have 3 or more terminals.

(c) Draw a transistor here.

5. (a) Get the box marked Unidentified Solid State Devices. Empty the contents in front of you.

(b) Get the boxes of diodes, rectifiers and transistors used in Learning Activity 1b. Sort the pile in front of you by placing them in front of one of the four boxes. To check your work you may look inside the boxes. If you were wrong place the component in front of the proper box.

You may try this activity again if you are not ready for the evaluation.

Student Evaluation:

1. Get an evaluation box and answer sheet for this unit, section E.

2. Follow the **directions** on the EVALUATION SHEET.

3. If you didn't name 8 components correctly do the Supplementary Activity below. See your instructor for help and further instructions.

Supplementary Activity

Repeat Learning Activity 5 - Use the boxes to help you sort the components.

Summary: You should be able to pick out and name DIODES, RECTIFIERS, and TRANSISTORS. Later you will use this information to learn the symbols which stand for each component and to learn what component is needed for assembly by reading its symbol on a diagram.

Optional Reading

Duarte and Duarte, Electronics Assembly Methods, McGraw-Hill Book Company, New York, 1964, pp. 96-102.

Herrington, Donald E., How to Read Schematic Diagrams, Howard W. Sams and Co., Inc., Indianapolis, 1967, pp. 69-77.

Johnson, Richard J., How to Build Electronic Equipment, John F. Rider Publisher, Inc., New York, 1962, pp. 196-200.

PROJECT 6

TROUBLESHOOTING (SHORTS AND OPENS)

OBJECTIVE:

a. Locate the malfunctioning component and identify the probable cause, given a schematic, malfunction symptom, and using the VOM multimeter. 100% accuracy required.

EQUIPMENT REQUIRED: Resistor-Diode trainer, fuse-switch block, VOM, and soldering equipment.

INTRODUCTION: In previous projects you used resistance and voltage measurements to demonstrate the characteristics of series and parallel circuits. In this project you will learn how to locate a bad or damaged component by comparing voltage drops and by making resistance checks between resistors of known and unknown values. In doing this you will have to use voltage-resistance relationships.

SUBOBJECTIVE: Given a series dc circuit, the input voltage and the voltage drop across a known resistance calculate an unknown resistance.

STEP 1. You can use the ratio (relationship) between voltage drop and resistance to determine the approximate resistance of an unknown resistor in a series circuit. To do this, you compare the voltage drop of the unknown resistor with the voltage drop of a known good resistor in relation to the ohmic value. In the following exercise, you are to make such comparisons with the resistors on the trainer board.

Connect jumper wires between 4B-4C and 4E-4F. Connect the low voltage power supply to the resistor diode trainer, as indicated below.

Power Supply		Resistor-Diode
+ terminal	to	1A
- terminal	through fuse-switch block	to 1G

Turn on the low voltage power supply and adjust to 10 vdc between points 1A and 1G of the resistor-diode trainer. Check this voltage with your VOM.

STEP 2. Measure and record the voltage drop across the following resistors.

Resistor 4AB ____________________

Resistor 4CD ____________________

Resistor 4DE ____________________

The voltage drop of 4AB is approximately 4.5 volts, 4CD has an approximate voltage drop of .45 volts, and 4DE has an approximate voltage drop of .45 volts. Which two resistors have about the same ohmic value? ____________

STEP 3. Resistors 4CD and 4DE have the same value because their voltage drops are approximately the same. What are the color code values of the two resistors? ____________________

STEP 4. The color codes indicate that both resistors are 1K resistors. Compare the color codes of resistors 4AB and 4FG. What are the color code values of both resistors?

STEP 5. Both resistors have a color code value of 10K. Measure and record the voltage drop of resistor 4FG. ____________________

STEP 6. The voltage drop of approximately 4.5 tells you that resistors 4AB and 4FG are both 10K resistors. If you know the voltage drop of an unknown resistor and the voltage drop and ohmic value of a known resistor in series with it you can determine the value of the unknown resistor. To prove this point, let's figure the value of resistor 4FG this way.

You know that the voltage drop across 4CD is .45 and its value is 1K. You also know that the drop across resistor 4FG is 4.5. The relationship (ratio) between these two resistors in series can be expressed as follows: The value of resistor 4FG is to the value of resistor 4CD as the voltage drop across 4FG is to the voltage drop across 4CD.

The first step is to find the ratio between the voltage drops across 4FG and 4CD. A ratio is expressed mathematically as a fraction:

$$\begin{array}{ll} \underline{4.5} & \text{(unknown resistor - 4FG)} \\ .45 & \text{(known resistor - 4CD)} \end{array}$$

So, divide 4.5 by .45.

STEP 7. The answer is 10. Thus, the ratio between the drops across 4Fg and 4CD is approximately 10 to 1. This is just another way of saying that the drop across 4FG is 10 times bigger than the drop across 4CD. (Remember, the greater the resistance, the greater the drop across it.) Therefore, the resistance of 4FG must be 10 times greater than the resistance of 4CD. And so, the ohmic value of 4FG is about 10K.

STEP 8. Take the assortment of four colored resistors from your storage box. Remove resistor 4FG from the trainer board. Install in its place the colored unknown resistors in the order asked for below.

What is the voltage drop of the gray resistor? ____________________________

The voltage drop across the gray resistor is 2v. What is the voltage drop for 4CD (1K)? ______________________ Don't forget to remeasure the drop across 4CD. The amount of drop changes when a different value resistor is put in series with it. What is the voltage drop ratio between the gray resistor and 4CD? ______________________________

It is $\frac{\text{(unknown)}}{\text{known}}\ \frac{2v}{.7} = 2.9$. The ratio between the voltage drops is about 3 to 1. Using the information from STEPS 6 and 7, compute the value of the gray resistor. ________________ 4CD is 1K; so 3 x 1K = 3K. Thus, the gray resistor is about 3K. Now measure the gray resistor. ________________ The meter also shows it to be 3K. Replace the gray with the red resistor. What is the drop across it? __________________________

The drop is 3 vdc. What is the ratio between it and the 10K resistor? ______________ This time the drop across the unknown is smaller than across the known resistor; so it is $\frac{(\text{unknown})}{\text{known}}$ = .5 to 1 or 1 to 2.

Therefore, the value of the unknown red is ______________, because it has one-half as much resistance as the 10K. Thus, .5 x 10K is 5K.

Measure and record the value of the red resistor now. It reads __________. The meter confirms that it is a 5K resistor. Now replace the red with the yellow resistor. What is the drop across it? ______________

The yellow resistor drops approximately 9v. What is the voltage drop ratio between the yellow and the 10K resistor? ______________

The ratio is approximately 10 to 1. What is the approximate ohmic value of the yellow resistor? ______________ Measure and record the value of the yellow resistor ______________.

The yellow resistor is approximately 100K, the meter reads 100K. Compare your readings with those that you computed using the voltage drop/resistance ratio. Your answers should be within 10 percent of each other. If not, repeat STEP 7. Return your trainer back to its orginal configuration. If your answers were within 10% continue on with Trainer Check 50.

TRAINER CHECK 50. Using the circuit in Figure 1, solve for R_x. Select the most nearly correct answer below.

a. 400Ω
b. 300Ω
c. 800Ω
d. 500Ω

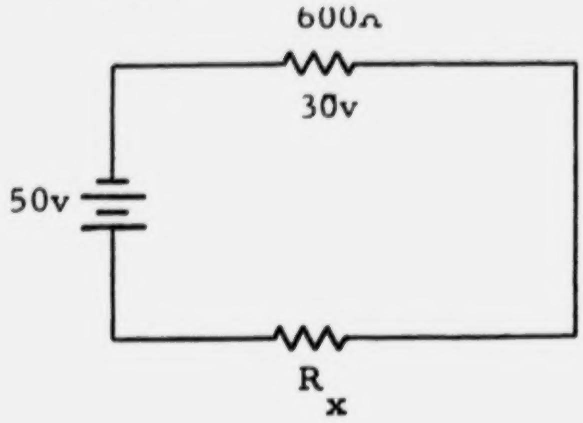


Figure 1.

STEP 9. Reading assignment: Pages 82-86, frames 4.91 to 4.123 Basic Electricity Book.

STEP 10. You learned in a series circuit that $R_t = R_1 + R_2 + R_3$ .... You can solve for any one unknown by rearranging the formula like this: $R_3 = R_t - R_1 - R_2$. Show your work on the next page.

If R_t = 50K
R_1 = 15K and
R_2 = 22K then
R_3 = ______________

STEP 11. R_3 = 13K. In the formula for total voltage,

$E_t = E_{R1} + E_{R2} + E_{R3}$ ....

E_t = applied voltage

E_{R1} = voltage drop across R_1

E_{R2} = voltage drop across R_2

E_{R3} = ______________________

STEP 12. E_{R3} equals the voltage drop across R_3. In the circuit in Figure 2 find the voltage drop of R_4. Use the formula $E_t = E_{R1} + E_{R2} + E_{R3}$. This formula can be rearranged in the same manner as done in STEP 10.

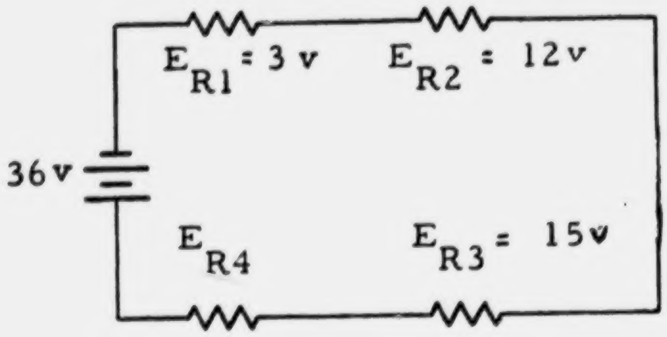


Figure 2.

Show your work.

STEP 13. The voltage drop of R_4 is 6v. The circuit in Figure 2 has a total current of 10 ma. What is the resistance of each of the resistors? If you need more information refer to project 3.

R_1 = ______________________ R_3 = ______________________

R_2 = ______________________ R_4 = ______________________

Show your work.

STEP 14. The resistors in Figure 2 have the following values: $R_1 = 300\Omega$ $R_2 = 1200\Omega$ $R_3 = 1500\Omega$ $R_4 = 600\Omega$. In the circuit of Figure 3, find the resistance of R_3.

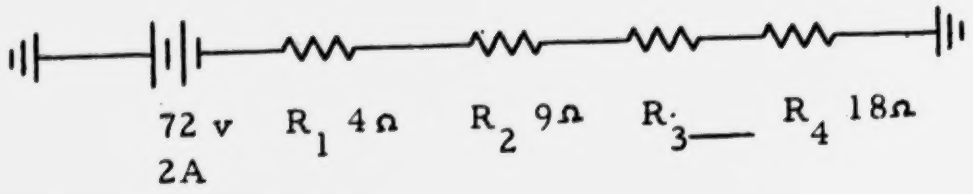


Figure 3.

R_3 ______________________

STEP 15. The resistance of R_3 is 5Ω . Using the circuit in Figure 3, find the voltage drop of R_3. ______________________

The voltage drop of R_3 is 10v. Use the schematic of Figure 4 and solve for the unknown resistance.

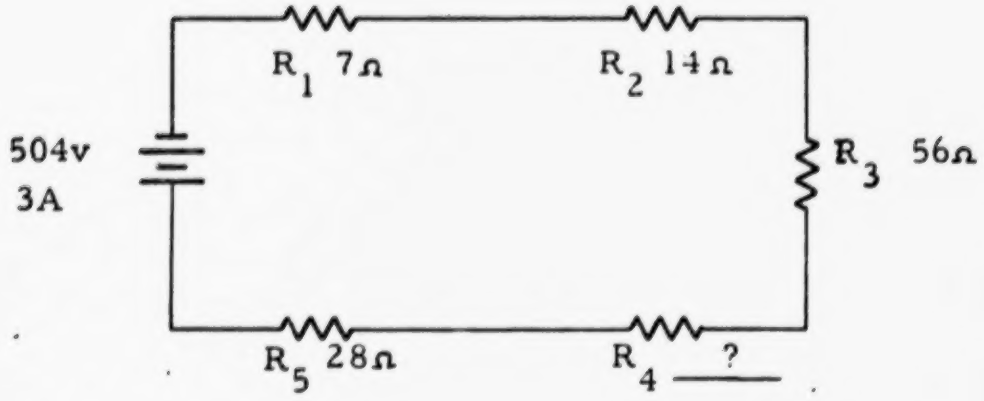


Figure 4.

R_4 ________________________

STEP 16. R_4 has a resistance of 63Ω. Find the voltage drop for each of the resistors in the schematic shown in Figure 4. R_1 ________________, R_2 ____________, R_3 ________________, R_4 ____________, R_5 __________.

STEP 17. The voltage drop of the resistors in Figure 4 follows: R_1 = 21v, R_2 = 42v, R_3 = 168v, R_4 = 189v, R_5 = 84v.

STEP 18. Place jumper wires between 4BC and 4EF. Check for 10 vdc between 1A and 1G on the Resistor-Diode trainer.

INSTRUCTOR CHECK. Measure the voltage drop across the test points in column 1 and record your reading in column 3 of Figure 5.

1 Test Point	2 Resistor Value	3 Voltage Readings	4 Voltage Readings	5 Difference Between 3 and 4
4AB	10K	________		
4CD	1K	________	________	____________________
4DE	1K	________	________	____________________
4FG	10K	________	________	____________________
Total	22K	Total ________	Total ________	

Figure 5.

Have your instructor check the answers on your chart.

STEP 19. The readings in Figure 5 indicate the size of the resistors. If resistor 4AB is a 10K resistor, then resistor 4FG must be a ____________ resistor. If resistor 4CD is a 1K resistor, the voltage drop across 4DE indicates it is a ________________ resistor.

STEP 20. 4FG is a 10K resistor and resistor 4CD is a 1K resistor. Remove the end of the jumper wire from 4B and solder it to 4A. Measure the voltage drops across 4CD, 4DE, and 4FG. Record your readings in column 4 of the chart in Figure 5.

STEP 21. Compare the voltage drops across 4CD, 4DE, and 4FG in column 3 to the voltage drops in column 4. Record the differences in column 5.

STEP 22. The voltage drops across the resistors in column 4 (increased/decreased).

STEP 23. The voltage drops increased. Did the ohmic value of the resistors change? ________________________

STEP 24. The value of the resistors did not change. Did the voltage drops in column 3 and column 4 remain approximately the same? _____________

STEP 25. The individual voltage drop did not remain approximately the same. In Figure 5, column 3, you measured the voltage drop across 4 resistors. In STEP 22, column 4, you measured the voltage drops across 3 resistors. What caused the change of voltage drops between column 3 and column 4? Check the correct answer.

a. The change of input voltage to the resistors.
b. The change in the number of resistors.
c. The change in the total resistance and the change in the applied voltage.

STEP 26. The change between column 3 and column 4 is caused by the change in the number of resistors. Turn off the power switch. Remove the end of the jumper wire from 4A and resolder it to 4B. Remove the end of the jumper wire from 4C and solder it to 4D.

Turn the power switch on.

Measure and record the following voltages.

4A to 4B ______________________________

4D to 4E ______________________________

4F to 4G ______________________________

STEP 27. You should have recorded these approximate voltage drops. 4AB is 4.6 volts, 4DE is .4 volts, and 4FG is 4.8 volts. Determine the resistance values of the resistors used in STEP 26 by either using an ohmmeter or resistor color code.

4A to 4B ____________________
4D to 4E ____________________
4F to 4G ____________________

STEP 28. The resistance of 4AB is 10K, 4DE is 1K, and 4FG is 10K. Which resistor had the smallest voltage drop? ____________________

STEP 29. Resistor 4DE had the smallest voltage drop. Which of the following statements is correct?

a. The largest resistor in a series circuit drops the smallest amount of voltage.
b. The smallest resistor in a series circuit drops the smallest amount of voltage.
c. If two or more like-valued resistors are connected in series, current will split into three equal parts.
d. If two or more like-valued resistors are connected in parallel, total current will remain the same throughout all branches of the circuit.

STEP 30. The smallest resistor in a series circuit drops the smallest amount of voltage. Turn the power supply off. Disconnect the Resistor-Diode trainer and give it to your instructor. The instructor will insert a bad resistor. You may complete Trainer Check 51 while the instructor has your trainer. Do not go beyond Trainer Check 51 until the instructor returns your trainer.

TRAINER CHECK 51. When troubleshooting a series DC circuit, the quickest way to isolate a malfunction is to:

a. compare the color-coded resistor value to the total current.
b. compare the color-coded resistor value to the actual measured value.
c. compare the color-coded resistor value to the individual branch currents.
d. compare the color-coded resistor value to the total voltage.

STEP 31. Do not connect the leads to your trainer board. Check your board and make sure you still have jumper wires between 4B-4C and 4E-4F. If not, insert them now.

STEP 32. Set the VOM to measure ohms.

INSTRUCTOR CHECK. Check the resistance of each resistor and record your readings on the chart in Figure 6.

Test Points	4AB	4CD	4DE	4FG
Measured Resistance				
Color-coded Value				
Voltage Drop				

Figure 6.

STEP 33. Write the color code value for each resistor in the spaces provided in Figure 6.

STEP 34. Reconnect the leads to the resistor-diode board, and, using the VOM, check the input to your trainer for 10 vdc. Adjust the power supply as necessary.

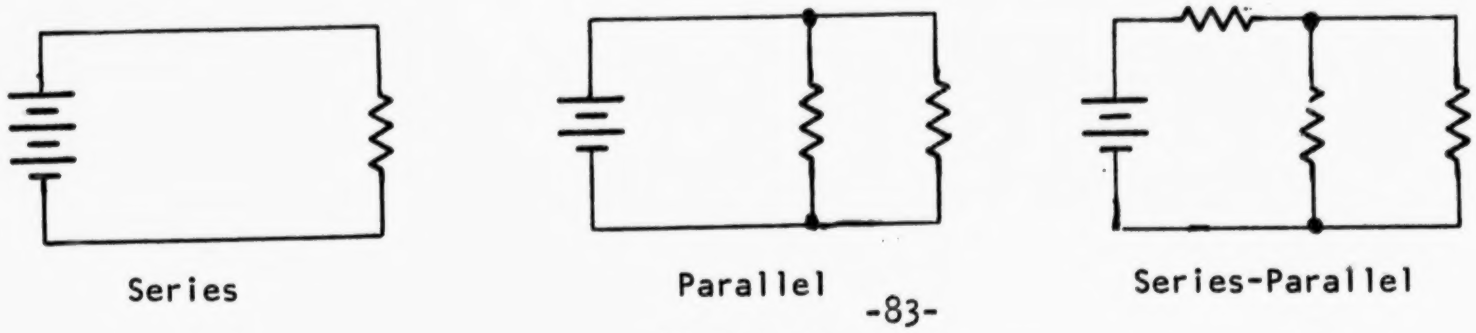
Measure the voltage drop across each of the resistors and record your readings in the spaces provided in Figure 6. Turn off the switch at the fuse-switch block and remove all jumper wires inserted by you, the student.

INSTRUCTOR CHECK. Now look at the voltage drop across each resistor and compare with the color code and measured resistance. Which resistor is bad? ______________________

Call the instructor to check your answers.

OBJECTIVE a. Locate the malfunctioning component and identify the probable cause, given a schematic, malfunction symptom, and using the VOM.

You have worked with all three of the basic DC circuits; series, parallel, and series-parallel. See Figure 7.



Series

Parallel

Series-Parallel

Figure 7.

Notice that these simple circuits consist only of a load (resistors), conductors (connecting wires), and a power source (battery).

Two very important components that are usually included in actual equipment have been left out: a fuse and a switch.

You know that when resistance decreases, current increases proportionately if voltage stays constant. If there is a large drop in resistance, the resulting large increase in current can damage components in the circuit.

However, the purpose of the fuse is to prevent this from happening. (Study the portion of Chapter 3, page 58, switches and fuses and frames 3.69 through 3.110).

"Troubleshooting" is a technique of the individual mechanic. While each of you will receive like technical training, it is highly unlikely that any two individuals will troubleshoot a circuit in the same manner.

This course is designed to acquaint you with various tools of troubleshooting, VOM, VTVM, oscilloscope and others. However, you, as an individual, have the most important tool of all - the "THINKER".

For every 100 troubleshooters, only a few are truly successful. Let us take the example of a blown fuse. Most of us would replace the fuse and say we found and replaced a bad component. No thinking is required of this task but what will happen when the circuit is turned on? That's right, we would more than likely replace another and another and another-- -------"fuse". Have you stopped to think beyond the fuse? The fuse opened for a "reason" or "cause." It is this "reason" or "cause" that the successful troubleshooter finds. Never replace a bad component and expect the circuit to function properly without further consideration. Check the circuit again -- be a "THINKER."

Construct the following circuit on the Resistor-Diode board.

STEP 35. Connect the power supply + terminal to point 1A on the Resistor-Diode trainer. Connect point 7A to 7D. Connect point 7E to 7G. Connect 1G to the fuse block, and from the fuse block the - terminal of the power supply.

The schematic of the circuit you made is shown in Figure 8.

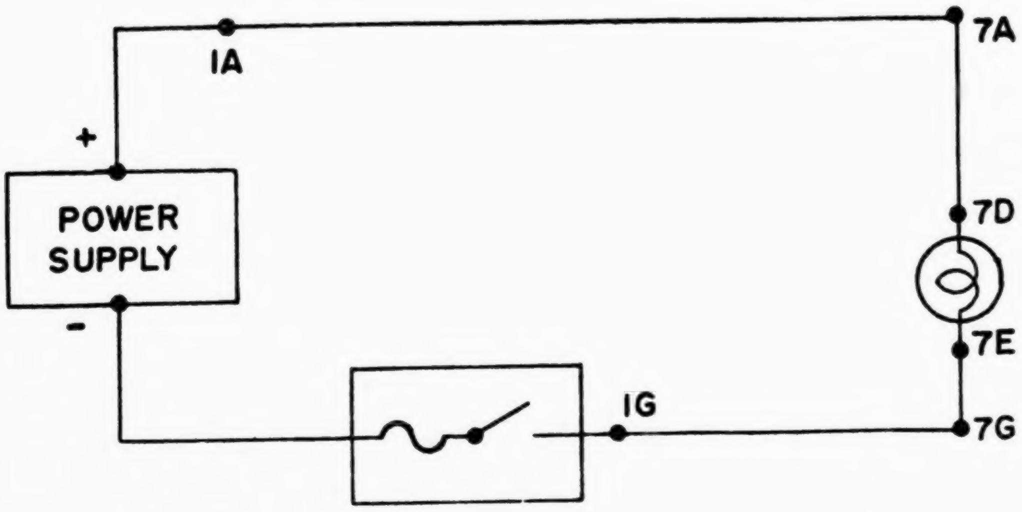


Figure 8.

The lamp is the only load device in the circuit.

STEP 36. Use the VOM and adjust the power supply for 10 vdc output.

STEP 37. Place the circuit switch to the ON position. (The light should go on).

STEP 38. Measure and record the voltage drops around the circuit between the points given below.

Across the fuse ________________

Across the switch ________________

Points 7D to 7E ________________

STEP 39. The only point you can get a usable voltage reading is between 7D-7E. You may get a .1 or .2 volt reading across the fuse. This is because the small resistance in the load causes the little amount of resistance in the fuse wire to seem large in comparison. Place the switch in the OFF position (light out).

Repeat the measurements of STEP 4.

Across the fuse ________________

Across the switch ________________

7D to 7E ________________

The voltage drop was across the switch this time. What does the voltage across the switch indicate to you?

a. The switch is open.

b. Lamp filament is OK.

c. The circuit from 1G to the +terminal of the power supply is complete.

d. The circuit from the fuse to the B- terminal of the power supply is complete.

e. All of the above.

You shouldn't have been fooled by that one. The object of the question was not to check your response but to give you a chance to analyze the circuit. Go over it again now.

The switch is open. Remember, an open is, in effect, a very, very high resistance. The voltmeter sees it as an infinite resistance across which all voltage is dropped. In a series circuit, the total voltage (applied voltage) will be measured across an open.

Lamp filament is OK -- in earlier projects you found that voltage drop is a measure of potential difference. In other words, a 10 volt difference in potential is measured across the switch. To have this potential difference at each side of the switch, the circuits from the power supply to each side of the switch have to be complete. Because the lamp filament makes up a part of this circuit, it too has to be good.

As a matter of fact, the same analogy can be applied to why c and d are correct. The point made here in analyzing this circuit is this. Many repairmen can use a meter, but only a good repairman knows what the meter is telling him.

STEP 40. Next, place the circuit switch in the ON position.

STEP 41. Make a voltage reading across points 7D and 7E (lamp).
Record ______________________

STEP 42. In circuits with a large resistance ratio between the load and the fuse, the applied voltage will be seen across the load. Check the applied voltage at the power supply terminals and the voltage across the lamp. You will notice they are almost identical. The reason you cannot see the difference is because of the range you are using on the VOM. Place, but do not solder, a piece of wire between point 7D and point 7E. The lamp should go out. Put the piece of wire to one side.

STEP 43. The circuit is now open somewhere. Now use the VOM to find the bad component by checking for a voltage drop. The bad component is the ______________________.

You should have identified the fuse as the bad component because of the voltage drop across it. Remember, the fuse is not the load device and so voltage drop across it means it must be open (blown) because of trouble in the circuit.

> NOTE: While the fuse is the present problem, it worked as it should have. By placing the jumper wire across the lamp, you, in effect, placed a very low resistance around the load. This shorted out (bypassed) the circuit load and eliminated all circuit resistance. Therefore, current became excessive and before the rest of the circuit could be damaged, the fuse blew and opened the circuit. When you removed the wire, you removed the short that caused the excessive current and blew the fuse.

Have your instructor replace the fuse. Use 1/2 or 3/4 amp.

STEP 44. Open the circuit switch (OFF) and install a jumper wire between points 7E and 8E. Your circuit will be as shown in Figure 9.

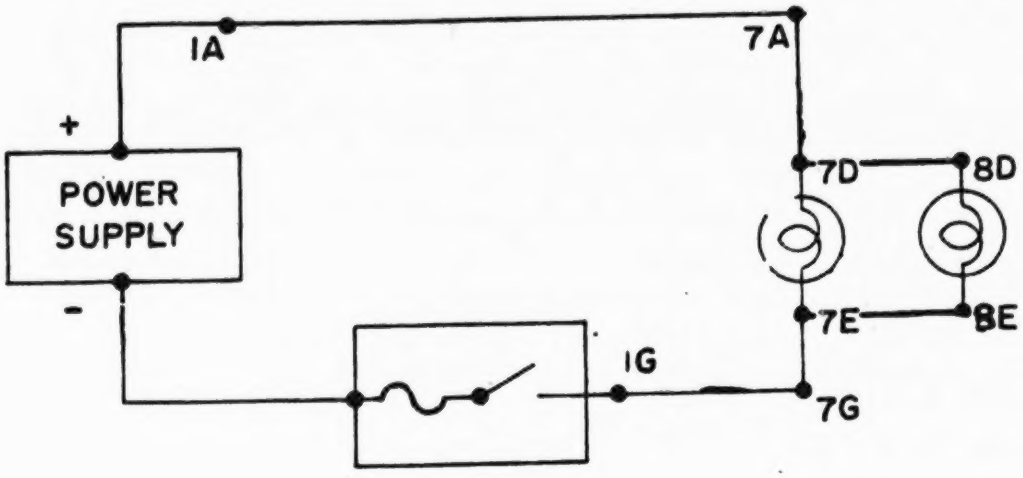


Figure 9.

STEP 45. What kind of a circuit did you construct? ______________________

STEP 46. This circuit, FOR TROUBLESHOOTING PURPOSES, is a series-parallel circuit with two lamps connected in parallel as the load, while the fuse and switch are both series components. This is because we have TOTAL current flow through the fuse and switch. Measure and record the resistance of the parallel circuit, (load) checking between points 7D and 7E.

____

STEP 47. The resistance should be about 35Ω using the x 10 scale. Now use Ohm's Law, $I = \frac{E}{R}$ to find the current. Use 10v, applied voltage.

STEP 48. The calculated value should be about .3 amps. Turn the circuit switch on. Use the VOM to measure total current. Record your reading ______________________

STEP 49. The current should be about .03 to .04 amp on the .1a scale. Your calculated current reading was about .3 amps. Why is there a difference?

With resistors, the cold resistance (when the circuit is off), and the hot resistance (when the circuit is on) is almost the same. However, in lamps, as well as in some other devices, the hot and cold resistance is very different. Let's prove this fact.

STEP 50. Use the measured value approximately .03 to .04 amps to calculate the hot resistance of the lamps.

The calculated value (hot resistance) of the two lamps is now about 300Ω to 350Ω as compared to approximately 35 ohms of measured value (cold resistance).

You must be careful when using an ohmmeter to check circuits. You sometimes can get erroneous readings when you are checking a circuit that has components that have different hot and cold resistances. You have seen that these resistances vary from a small value to a large value. When possible, do your troubleshooting with power on the circuit and check current and voltage. Don't check resistance with power on.

STEP 51. Use a jumper wire and short (create a low resistance path) between 8D and 8E. As you short it, watch the fuse.

The same thing happened here as in the series circuit. The fuse blew, making the circuit incomplete. Measure the voltage drop across the fuse. You should have 10 vdc.

It should be clear by now that if a fuse opens a circuit, the cause is excessive current. Chances are that one or more components have been shorted. So, you shouldn't attempt to troubleshoot a shorted circuit with power on because that will lead to a large pile of blown fuses. With a shorted circuit, you have to find the trouble by means of resistance or continuity checks.

STEP 52. Make the necessary circuit changes to duplicate the schematic in Figure 10.

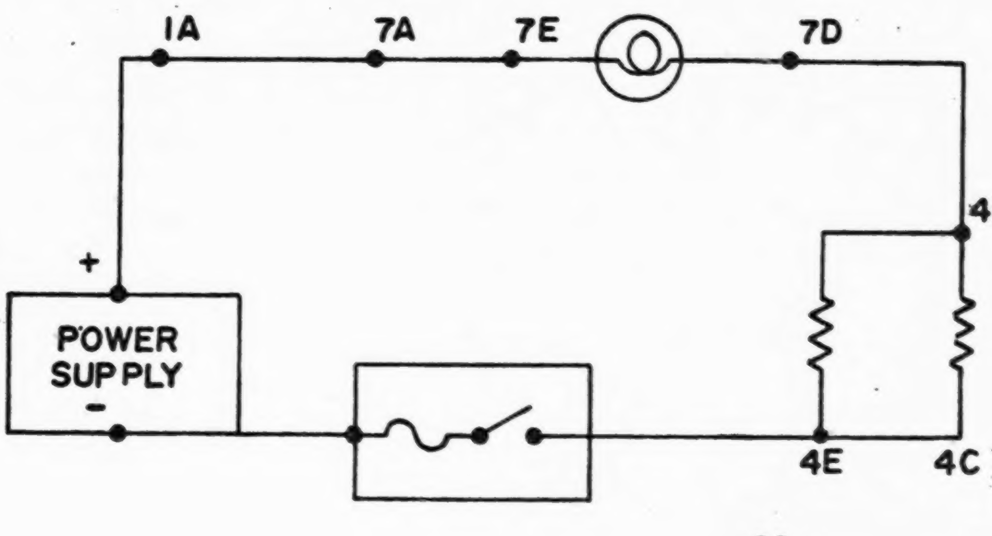


Figure 10.

What type of circuit have you constructed?

The constructed circuit is series-parallel. The lamp, switch, and fuse are the series components and the two 1K resistors form the parallel network.

STEP 53. What is the total equivalent (cold) resistance of the entire circuit? ______________________________

STEP 54. The equivalent cold resistance of the circuit is approximately 570Ω. Have your instructor insert a fuse in the fuse-switch block. If you constructed your circuit according to the schematic you should have turned off (opened) the switch. Now turn on (close) the switch.

INSTRUCTOR NOTE: The instructor can insert a 1/16A fuse.

Use a jumper wire to short between points 4D and 4E. Did the circuit current increase? __________ Did the fuse blow? ____________

You should have noticed that the lamp glowed with a greater brilliance. This means there was a rise in current through the lamp. The current increased because you shorted out the parallel network with an equivalent resistance of 500 ohms. The current could only increase because total circuit resistance decreased. The fuse did not blow (open the circuit) because the increase was not excessive. You must remember, that in a series-parallel circuit, the fuse will not in all cases open the circuits, because the remaining parts of the circuit can often handle the increase in current flow if it is not excessive.

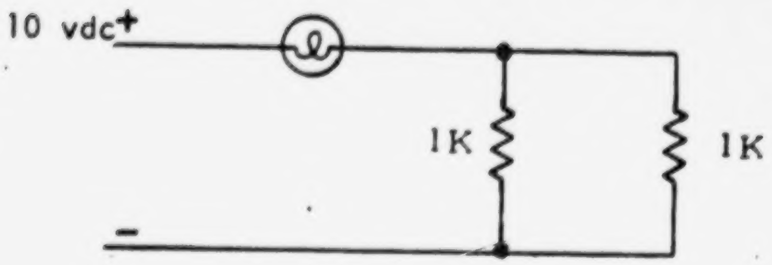
STEP 55. Using a jumper wire, short between points 7D and 7E. Did the fuse open the circuit? ______________ Did the lamp go out? ________

When you shorted across the lamp it went out. But, when you removed the short the lamp came on. Therefore, the fuse did not blow. However, the lamp did go out while it was shorted. Thus, when a component is shorted by a low resistance path, that component will be inoperative but the remaining circuit load, providing the increase in current is not excessive, can sometimes handle the increase in current flow. The components will probably function satisfactorily for a time, but prolonged operation with the higher current may damage the components.

Turn the switch off. Disconnect one end of either of the 1K resistors at point 4D and leave it free. Turn the switch on and watch the lamp. The brightness of the lamp (increased/decreased/remained the same?)

____

The brightness of the lamp decreased. Why did the lamp go out? You took one of the resistors out of the circuit, yet the resistance apparently increased. What has happened here? Explain this to your instructor before going on.



Refer to the following illustration.

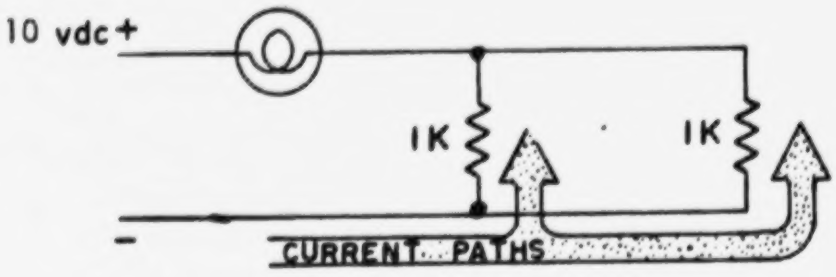


Figure 11.

The equivalent resistance of the parallel portion of the circuit in Figure 11 is 500Ω. The total circuit resistance as shown in the above illustration is 500Ω + the lamp resistance.

When one of the parallel resistors is open (in effect, removed from the circuit) the total resistances increases. See the circuit of Figure 12.

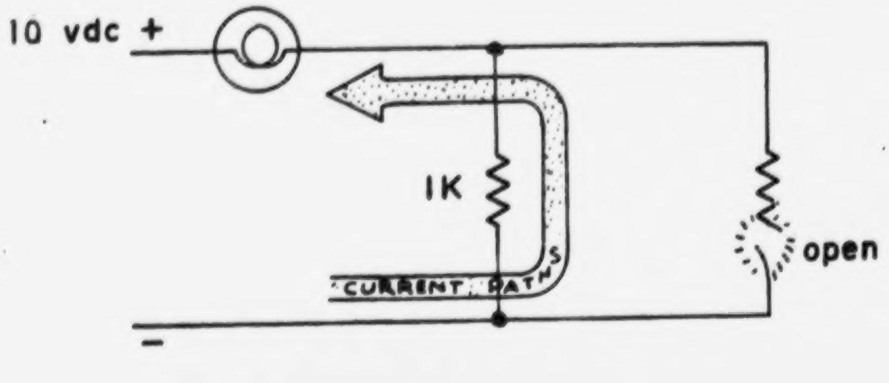


Figure 12.

The current now meets a resistnace equal to 1K, plus the lamp. Therefore, the total resistance has increased and the total current has decreased as shown by the lowered brightness of the lamp.

This proves that if a branch of a parallel circuit opens or is shorted out the total circuit resistance will increase and the total circuit current will decrease.

If the lamp or any other series component becomes open, the complete circuit will be inoperative, because in a series-parallel circuit the total current must flow through the series components. IF THE CURRENT CANNOT FLOW, THE CIRCUIT IS NOT COMPLETE.

Use Figure 13 for all four trainer check problems that follow.

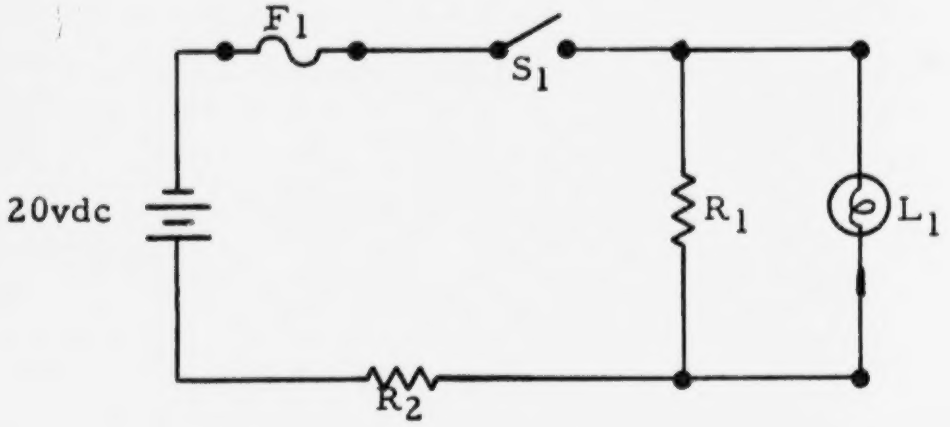


Figure 13.

TRAINER CHECK 52. The lamp L_1 is out and resistor R_2 has a 5 vdc drop across it. What is wrong?

- a. Switch S_1 is open.
- b. Resistor R_1 is open.
- c. Lamp L_1 is open.
- d. Resistor R_2 is open.

TRAINER CHECK 53. The lamp L_1 is out and the voltage drops across switch S_1, fuse F_1, and lamp L_1 are all 0 vdc. What is wrong?

- a. Switch S_1 is open.
- b. Lamp L_1 is open.
- c. Resistor R_1 is open.
- d. Resistor R_2 is open.

TRAINER CHECK 54. The light L_1 is out and the voltage drop across it is 0 vdc. The drop across resistor R_2 is 10 vdc. What is wrong?

- a. Resistor R_1 is shorted.
- b. Lamp L_1 is open.
- c. Resistor R_2 is shorted.
- d. Switch S_1 is open.

TRAINER CHECK 55. The lamp L_1 is ON, but is brighter than normal. What is wrong?

a. Resistor R_1 is shorted.

b. Resistor R_1 is open.

c. Lamp L_1 is shorted.

d. Resistor R_2 is open.

SUMMARY: The latter part of this project dealt with "opens" and "bypass-shorts" in series, parallel, and series-parallel circuits. You first constructed each of these circuits and then made opens with a switch, and bypass-shorts with a piece of wire.

The open was identified by the maximum voltage drops across it. This proved that the parts of the circuits on each side of the open(switch) were complete. An open in a branch of a parallel circuit caused the current to decrease because of the increase in circuit resistance. The open in the parallel portion of the series parallel circuit caused a decrease in current because of the increase in the circuit resistance.

The short or low resistance bypass in series circuit caused excessive current; thus, causing the fuse to blow and open the circuit. If there were two or more components in series, the fuse may not blow, but higher than normal current would be present in the circuit. If, for instance, a motor was one of these components, it could be damaged.

You noticed a marked difference between hot and cold resistance and you were told to troubleshoot, when possible, with power on the circuit.

A parallel circuit reacted to a low resistance path (short) the same as a series circuit. However, the series-parallel circuit reacted differently. The shorted component became inoperative and did not blow the fuse and the remaining components continued to function with increased current. If this condition were allowed to continue, these components could be damaged.

This exercise should have proved to you that you have to do more than just read the meter. You have to know what the reading means each time you measure resistance, current, or voltage. An increase or decrease in any one of them can indicate entirely different kinds of trouble, depending on the type of circuit you are checking. Look beyond the bad component -- be a thinker.

TRAINEE NOTES:

PROJECT 25

RESONANCE

OBJECTIVES:

a. Determine the "bandwidth" and "bandpass frequencies" of a series RCL circuit, using a VTVM. The value of bandwidth must be accurate to within ± 10%.

b. Determine the "bandwidth" and "bandpass frequencies" of a parallel RCL circuit, using a VTVM. The value of bandwidth must be accurate to within ± 10%.

c. Identify the tank circuit branch with the greater current when a frequency above or below resonance is applied, using an ac ammeter. Circuit must be identified as inductive or capacitive.

EQUIPMENT REQUIRED: Reactive circuits trainer, decade inductor, decade capacitor, VTVM, ac milliammeter, and oscilloscope.

INTRODUCTION: Up to this point in the reactive circuits area, you have been concerned with the different types of reactive circuits and their components. You have seen what effect the changing of frequency and reactive component values (inductance and capacitance) have on circuit operation. In this project you will still be concerned with reactive circuits, and what happens when a circuit is at the point called "resonance". Resonance, by definition is the condition in a circuit containing inductance and capacitance where the inductive reactance is equal to the capacitive reactance. This condition occurs at only one frequency for fixed values of L and C. As you remember from previous projects, a capacitor stores energy during one half cycle and returns this energy during the next. An inductor also stores energy during one half cycle and returns it during the next half cycle. The capacitor and inductor do not store energy on the same half cycle. When the capacitor is storing, the inductor is releasing it. When the inductor is storing energy the capacitor is releasing it. This makes it possible for the inductor and capacitor to pass the same energy back and forth. The rate at which this energy is transferred can be called the resonant frequency.

There are two main uses for parallel resonant circuits. The most important of these is the selection of a single frequency or a narrow band of frequencies. This is called tuning. This is possible since the impedance across a parallel resonant circuit and consequently, the voltage are maximum at the resonant frequency and decreases to very low values on either side of resonance. Some circuits of this this type are made up of fixed components so that the circuit has a fixed frequency. The most common, however, is the variable-tuned circuit. This type of circuit can be tuned to a certain frequency or narrow band of frequencies within a wide band of frequencies. Tuning is usually accomplised by a variable capacitor. The minimum amount of capacitance and the fixed inductance determine the highest frequency that can be selected, and the maximum amount of capacitance and the fixed inductance determine the lowest frequency. The variable capacitor used in your radio receiver has a minimum capacitance of about 35 micro-microfarad and a maximum capacitance of about 365 micro-microfarad. When this capacitor is connected in parallel with a .28 millihenry coil, the circuit can be tuned to any frequency in the broadcast frequency range (550-1600 kilocycles). Some circuits are tuned by varying the inductance. Inductive tuning is most common in radar or other microwave equipment. These variable inductors are usually of the powdered-iron core type. The second application of a parallel-resonant circuit is a frequency rejection "filter" or trap. When used for this purpose, the circuit is placed in series with a line delivering voltages at the desired frequencies to the proper circuit. Since the impedance across this type of circuit is maximum at resonance, it will drop most of the voltage at the unwanted frequency and pass most of the voltages at the desired frequencies.

A parallel resonant circuit that is used for tuning may also be called a series resonant circuit. Within itself, it is a series resonant circuit. When a voltage is induced into the coil part of the circuit the coil actually acts as the source of current. Therefore, this effective voltage source is in series with the inductance of the coil and with the capacitor. Maximum current flows within the circuit. This maximum flow characteristic is the distinguishing feature of a series resonant circuit. Applications of a series resonant circuit are, therefore, also those of frequency selection or tuning. Series resonant circuits are also used to reject one frequency or a narrow band of frequencies from a wide band of frequencies.

OBJECTIVE a. Determine the "bandwidth" and "bandpass frequencies" of a series RCL circuit, using a VTVM.

STEP 1. Construct the circuit of Figure 1, using the decade capacitor, the decade inductor and 100 ohm resistor of the reactive circuits trainer.

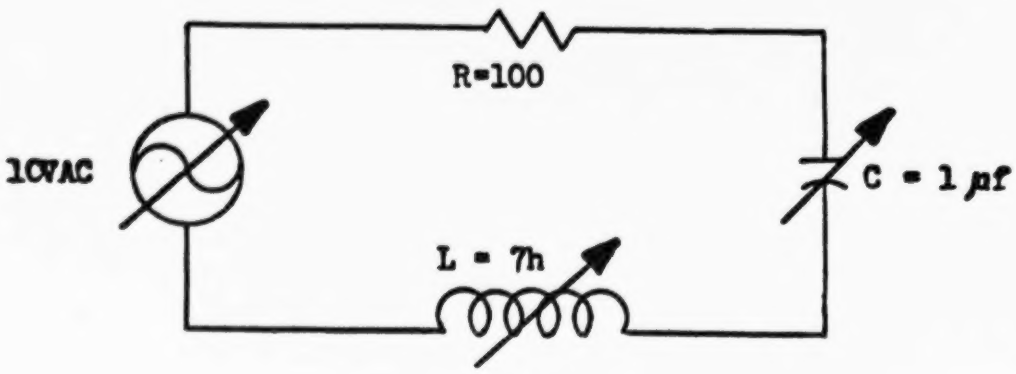


Figure 1

STEP 2. Adjust the input to 10 VAC as checked with the VTVM. Set the frequency of the sine-generator to minimum.

STEP 3. Connect the VTVM across the 100 ohm resistor. You are now going to plot a response curve for the constructed RCL series circuit. Note the graph of Figure 2.

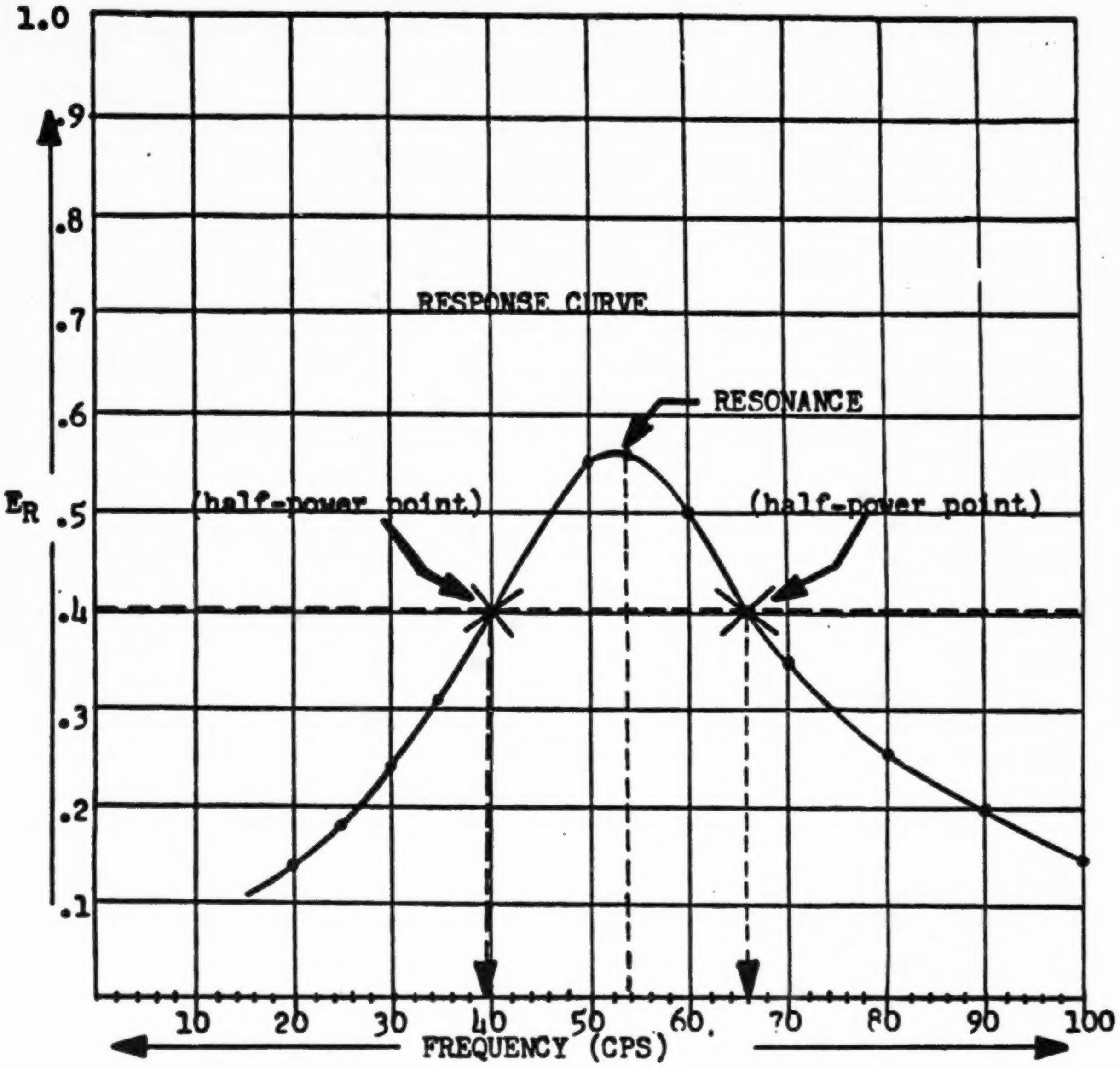


Figure 2

Frequency is plotted along the horizontal and resistor voltage on the vertical. The response of the series RCL circuit is charted by making a voltage reading across the resistor for each numerically marked frequency of the sine-generator frequency dial. The voltage readings for frequency were:

.14 for 20 CPS.
.18 for 25 CPS.
.23 for 30 CPS.
.31 for 35 CPS.
.4 for 40 CPS.
.55 for 50 CPS.

NOTE: The point of resonance was found by plotting the maximum voltage drop across the resistor. This was near 54 CPS. $E_R = .57$ volts

.5 for 60 CPS.
.35 for 70 CPS.
.25 for 80 CPS.
.2 for 90 CPS.
.15 for 100 CPS.

STEP 4. Recheck these readings at each frequency.

STEP 5. To determine bandwidth and bandpass frequencies it is necessary to find the "half-power points" of the response curve. The half-power points are found by multiplying .707 times the E_R at resonance. Example:

$$\begin{array}{r} .57 \\ \underline{.707} \\ 399 \\ \underline{3990} \\ .40299 \end{array}$$

The voltage at half-power is slightly over .4 volts. A broken line is drawn horizontally at this voltage level. The two points, where this broken line intersects with the response curve, are known as "half-power points".

It is necessary to determine the half-power points of the response curve to:

a. determine the bandwidth.
b. determine the resonance frequency.
c. determine the effective voltage.
d. determine the peak voltage.

Determining the half-power points is necessary to determine the bandwidth. The half-power points on the reponse curve are:

a. an equal voltage above and below resonance.
b. only determined above resonance.
c. only determined below resonance
d. only needed when determining the narrow bandwidth.

Since the half-power points are an equal voltage below and above resonance, these half-power points indicate the:

a. bandwidth.
b. resonance.
c. effective voltage.
d. impedance.

The half-power points indicate the bandwidth, and the half-power points are found by multiplying the:

a. E_R x .707.
c. X_C x .707.
b. X_L x .707.
d. I x .707.

The half-power points are found by multiplying E_R x .707.

STEP 6. The bandpass frequencies are from about 40 CPS to 66 CPS. These frequencies are found by looking at the half-power point frequencies.

The bandpass frequencies of an RCL circuit are those frequencies which result in a minimum E_R drop of .707 x E_R at resonance. The frequencies between 40 and 66 cycles per second meet this standard.

STEP 7. The bandwidth is nothing more than the number of cycles between the half-power points. The bandwidth is found by subtracting the low frequency from the high frequency. Example:

66 High frequency
40 Low frequency
(26 Cycle bandwidth)

STEP 8. Set the decade capacitor to 1.1 microfarad and the decade inductor to 10 henries.

a. Plot a response curve on the graph of Figure 3.

b. Determine and identify the resonant frequency on the graph.

c. Determine and identify the half-power points on the graph.

d. Record the bandpass frequencies.

e. Record the bandwidth.

__________________ to __________________ CPS (BANDPASS FREQUENCY)

__________________ CYCLES (BANDWIDTH)

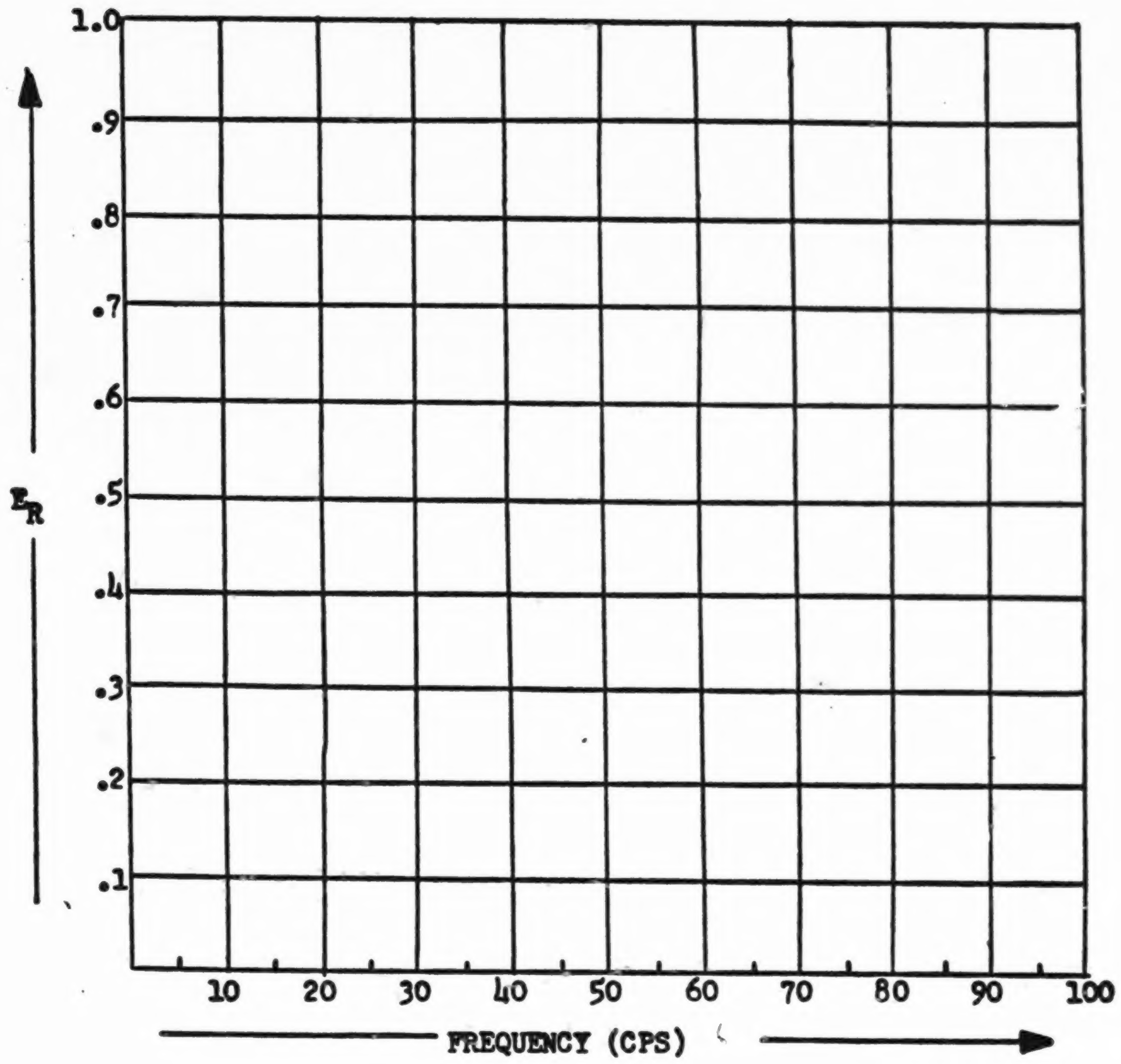


Figure 3

a. The response curve should be similar to the one plotted in Figure 4.

b. The resonant frequency is about 47 CPS.

c. The half-power points should be marked on the curve at about 35 and 62 CPS.

d. Bandpass frequencies are from 35 to 62 CPS.

d. You should have a 27 cycle bandwidth.

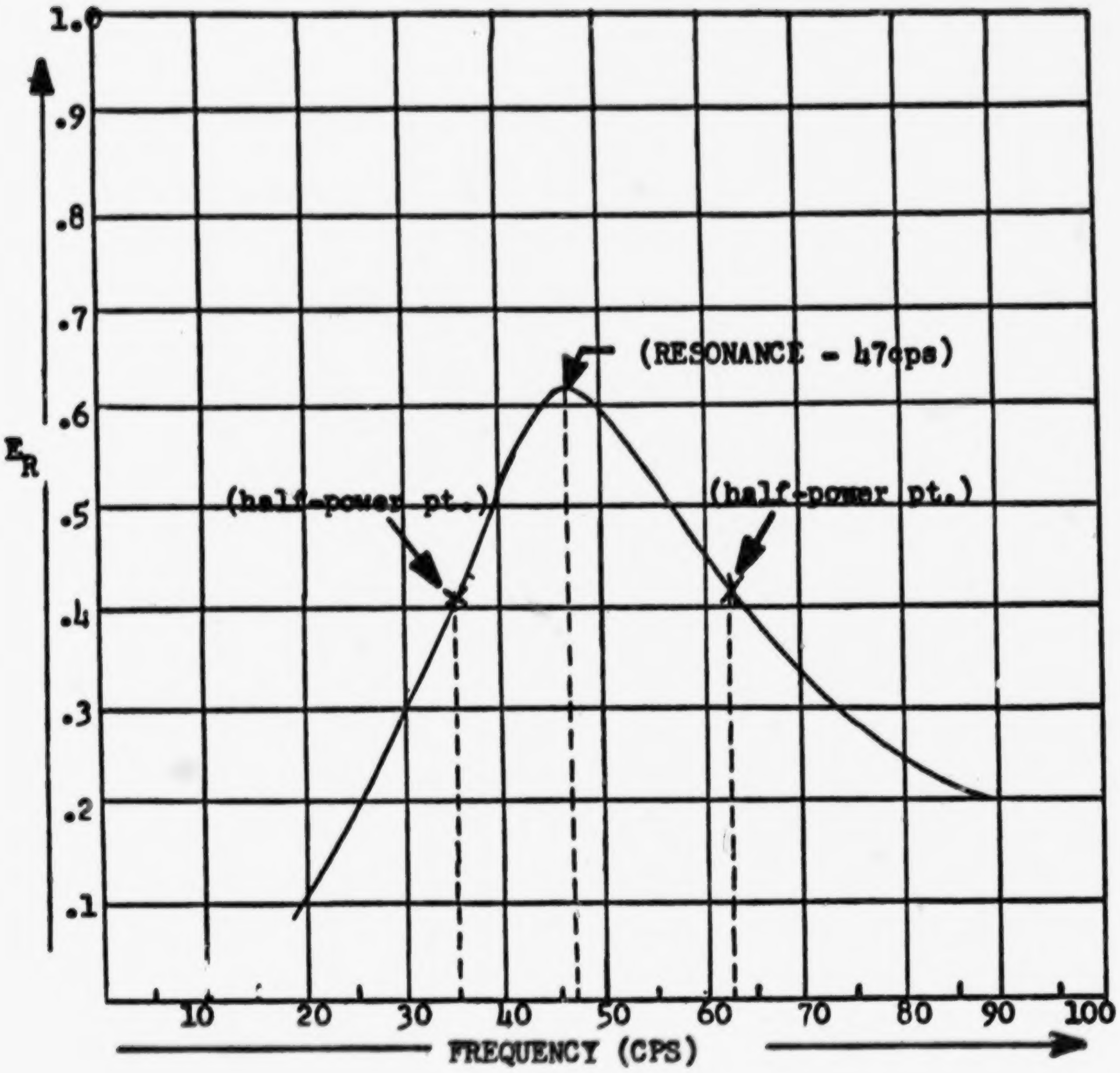

1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
E_R
(RESONANCE - 47cps)
(half-power pt.)
(half-power pt.)
10
20
30
40
50
60
70
80
90
100
FREQUENCY (CPS)

Figure 4

In review, consider the series RCL circuit whose resonance curve is shown in Figure 5.

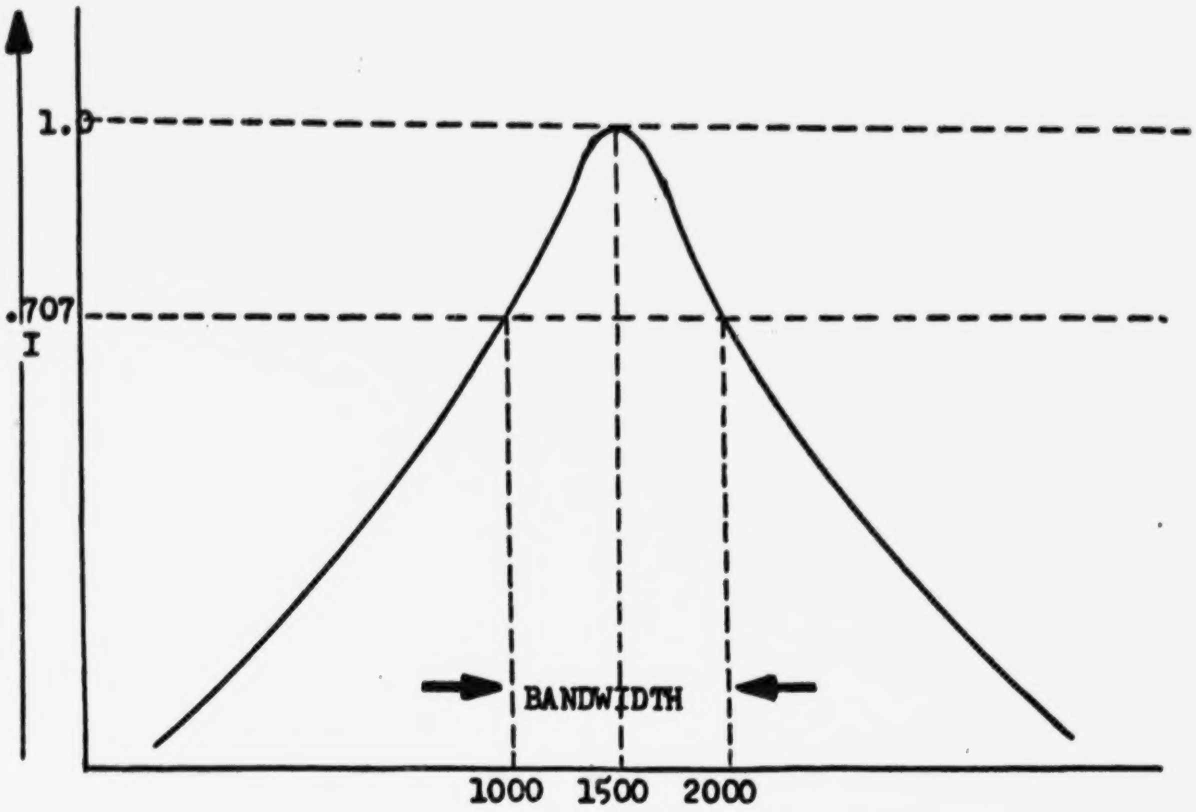


Figure 5

Note that circuit current is charted vertically in place of resistor voltage. Half-power points are found in the same manner, .707 x I (MAX). As the frequency is varied through resonance, the current increases from some low value to a maximum and then decreases to a low value again. The current flow is maximum at the resonant frequency and diminishes slightly at frequencies just below and just above resonance. Those frequencies at which current flow is comparatively great are called a bandpass of frequencies or just "band". The bandwidth is the difference between the highest and lowest frequencies contained in the band. Those frequencies just outside the band allow almost as much current to flow as those just inside the band. What determines the width of the band? Where should the dividing line be? The standard that has been universally adopted states that the limiting frequencies which mark the two edges of the band are those at either side of resonance at which the current or voltage falls to .707 of the current or voltage at maximum or resonance. In other words, the half-power points.

In a series RCL circuit, those frequencies at which current flow is comparatively great are called:

a. bandpass of frequencies.
b. diminished frequencies.
c. bandwidth of frequencies.
d. resonance frequencies.

The frequencies at which current flow is comparatively great are called bandpass frequencies or just "band". The bandwidth is the difference between:

a. the highest and lowest frequency contained in the band.
b. the lowest frequency and resonance.
c. resonance and the highest frequency.

The tuning circuit of a radio must be selective. That is, it must tune to a very narrow band so that other frequencies will be discriminated against or blocked out. Otherwise, your radio receiver would present you with a bunch of stations and no one station would be heard. The "Q" of a resonant circuit determines the circuit's selectivity. The selectivity of a resonant circuit is the ability of the circuit to discriminate between several frequencies that are close together. For example, assume that two voltages at two different frequencies are fed into the parallel LC circuit of Figure 6. Call these frequencies A and B.

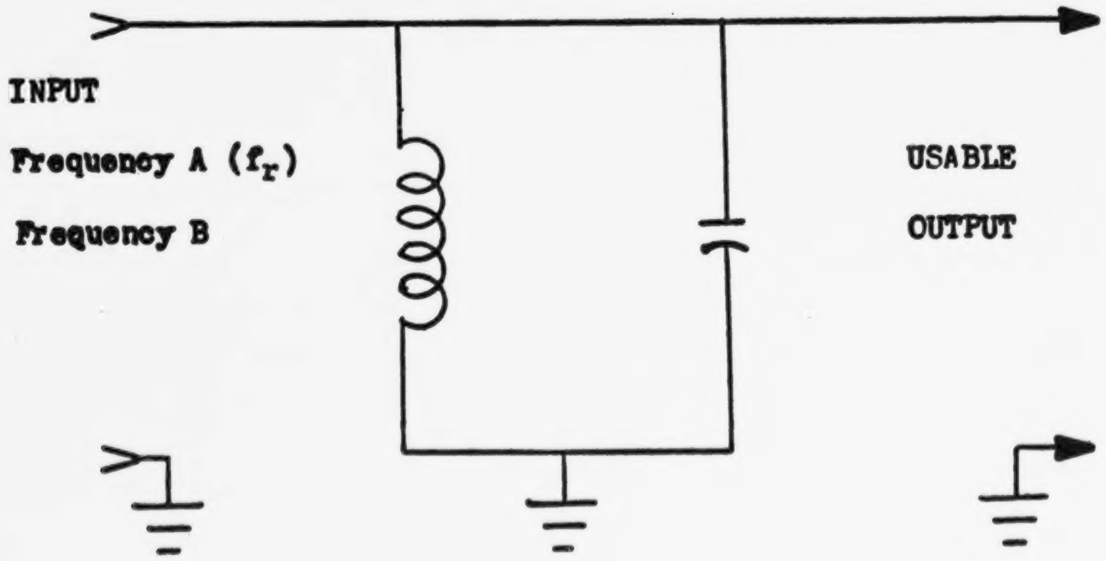


Figure 6

Suppose that frequency A is the resonant frequency of the circuit. Both input voltages tend to cause circulating currents to flow. That is, both cause energy to be stored alternately in the capacitor and in the inductor. As a result of these circulating currents, a usable amount of voltage is developed across the coil or capacitor at the resonant frequency A, but practically no voltage is developed at frequency B. You can then say that the circuit has discriminated against frequency B.

The steepness of the resonance curve indicates the amount of selectivity while the height indicates strength of the signal. (See Figure 7.) If the circuit has a high "Q" and, therefore, a steep resonance curve, its selectivity is good. If there is a relatively large resistance in the circuit, the resonance curve will not be very steep and the selectivity will be poor. The difference in voltages developed at frequencies A and B in the high-Q circuit is 5 1/2 volts. The difference in voltages developed at the same two frequencies by the low-Q circuit is only 2 1/2 volts.

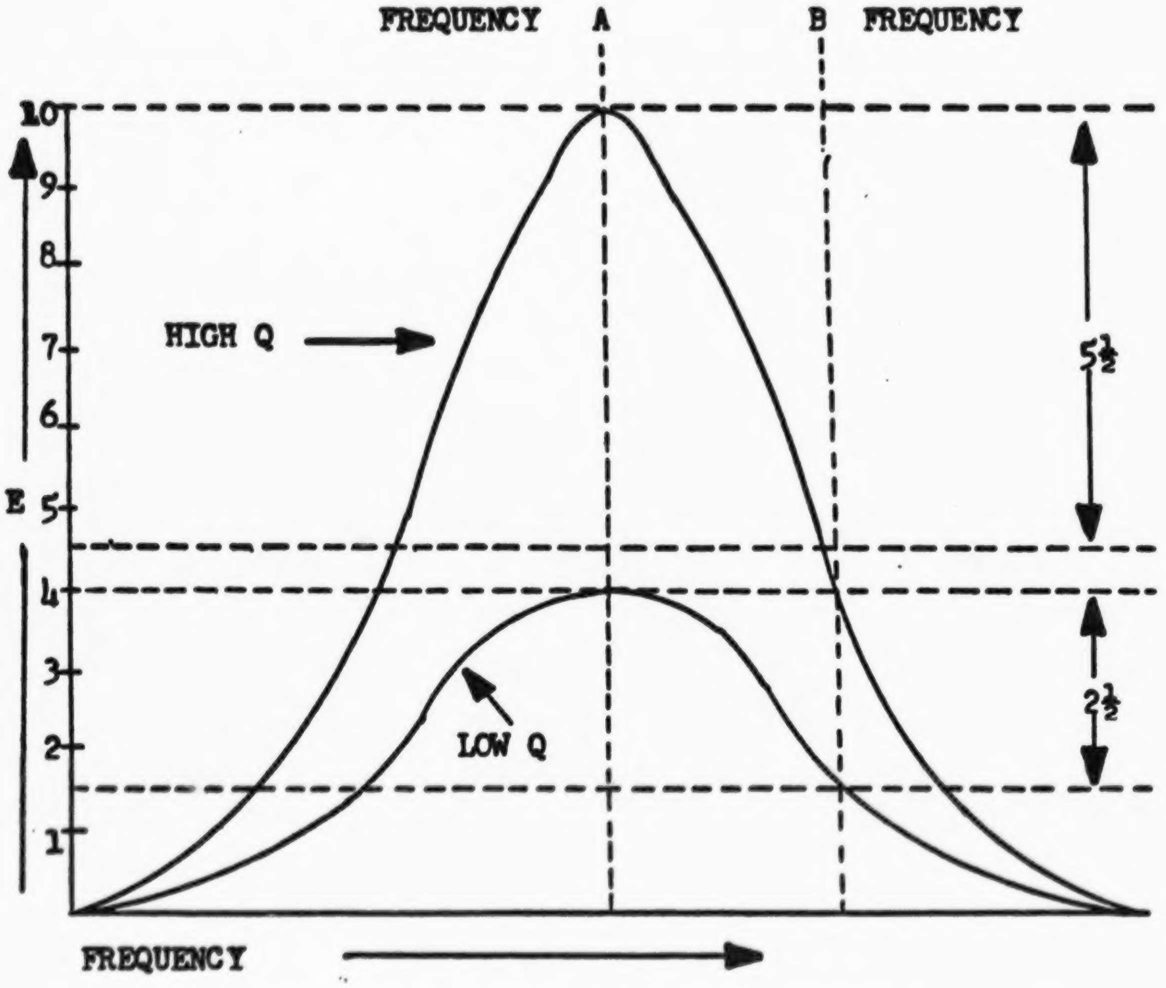


Figure 7

From the foregoing discussion it can be said that a high-Q circuit will have a higher gain, narrower bandwidth and better selectivity than a low "Q".

STEP 9. Construct the circuit as illustrated in Figure 8.

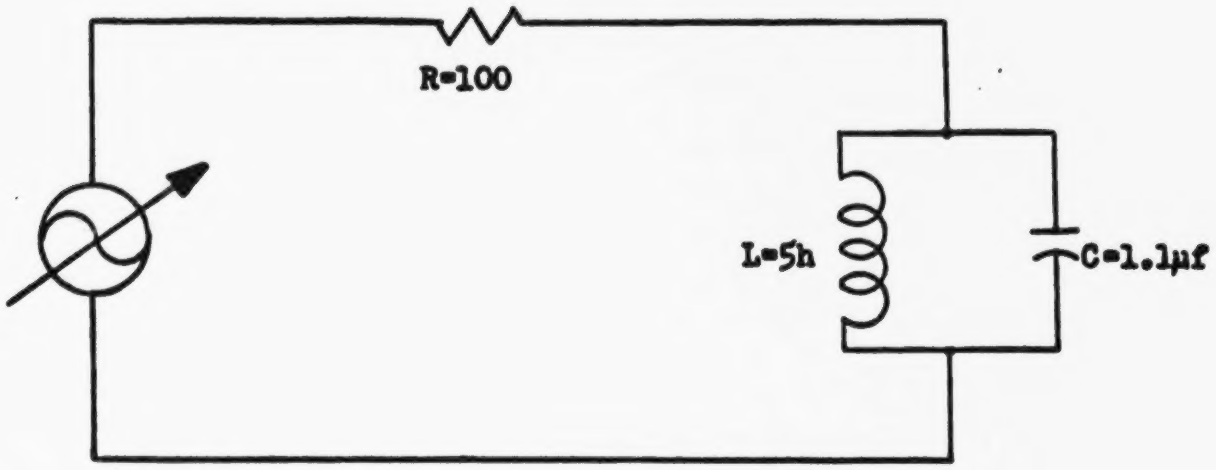


Figure 8

Note that the circuit to be used is a series-parallel circuit. The parallel network is a combination of L and C which forms a TANK.

OBJECTIVE b. Determine the "bandwidth" and "bandpass frequencies" of a parallel RCL circuit, using a VTVM.

STEP 10. Make the following adjustments and settings on your constructed circuit.

a. Decade inductor to 5 henries.

b. Decade capacitor to 1.1 microfarads.

c. Adjust the sine-generator output to 10 volts.

d. Set the frequency to minimum.

STEP 11. Plot a resonance curve for this circuit on the graph of Figure 9. Use your VTVM connected across the tank to obtain the voltage readings. (Set the tank voltage to 10 at resonance.)

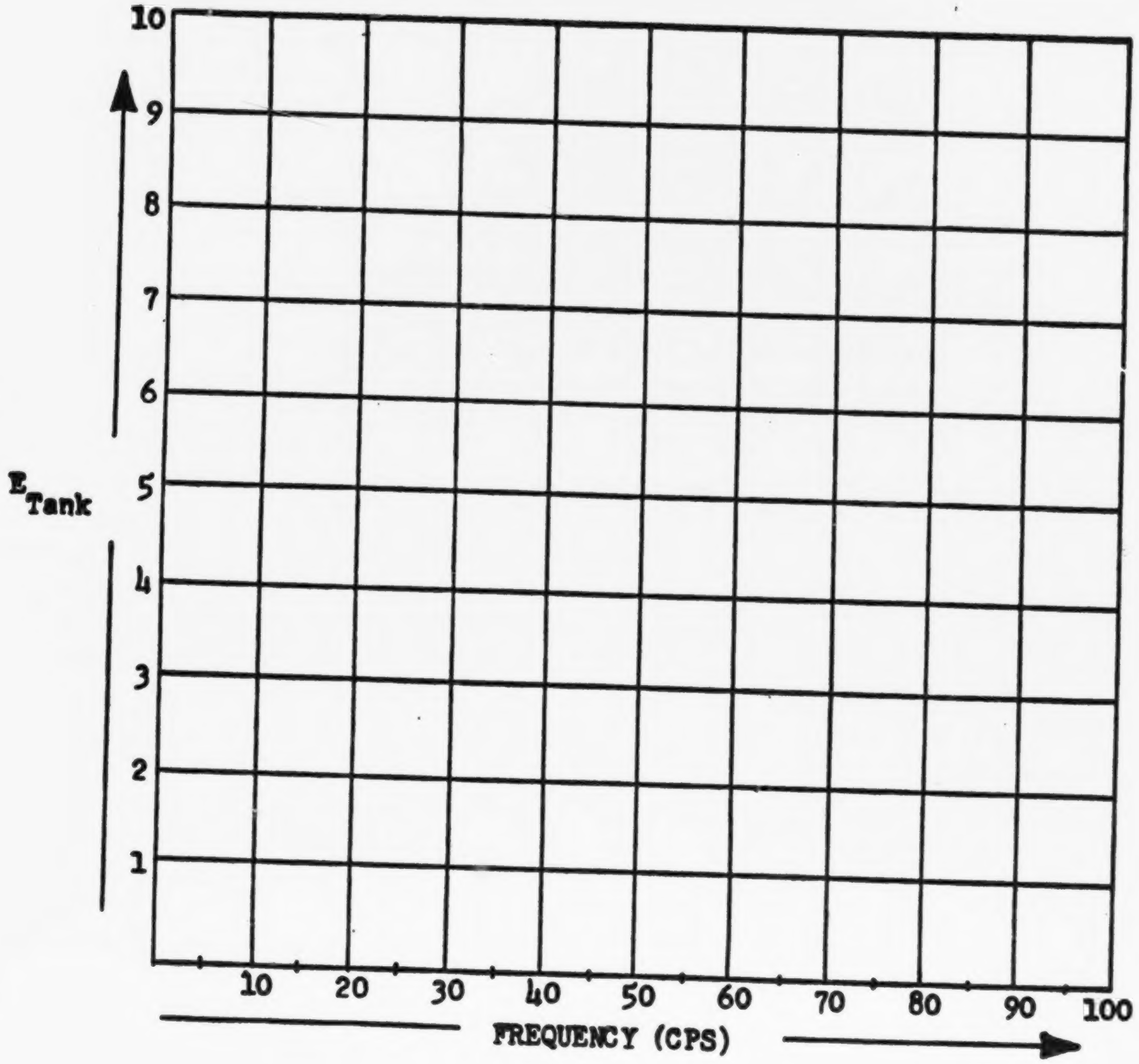


Figure 9

STEP 12. Record the resonant frequency.

f_r = ____________________________

STEP 13. Record the bandpass frequencies.

__________________ to __________________ CPS.

STEP 14. Record the bandwidth of the parallel LC circuit.

___________________________ cycles.

The parallel LC circuit presents a high impedance to the resonant frequency and results in a high voltage drop. This is desirable because the output will be taken across the tank. Above and below resonance the amplitude drops sharply indicated by the resonance response curve. The steepness of the amplitude change is a measure of the circut "Q". The higher the Q, the better the selectivity as in the series RCL circuit.

The resistor was used in the circuit to demonstrate the loss of signal voltage when a frequency other than resonance is applied.

STEP 15. Set the input frequency to resonance. Measure and record the voltage across the resistor and the tank.

AT RESONANCE E_R = __________ volts E_{TANK} = _________ volts

STEP 16. Set the frequency above resonance (80 CPS.)

ABOVE RESONANCE E_R = _______ volts E_{TANK} = _________ volts

STEP 17. Set the frequency below resonance (40 CPS.)

BELOW RESONANCE E_R = _______ volts E_{TANK} = _________ volts

The recorded voltages should indicate loss of signal across circuit resistance when the signal is not at the resonant frequency. As long as the signal is at the resonant frequency, line current is minimum. Line current increases above or below resonance and this gives rise to the voltage across the line resistance and consequently, loss of signal voltage developed across the tank.

(The response curve for 5 henries and 1.1 microfarad is shown in Figure 10.)

The resonance frequency is near 70 CPS. Bandpass frequencies are about 25 to 155 CPS. The bandwidth is 130 cycles ± 10%.

NOTE: This circuit would not be very selective (low Q) as it has considerable resistance resulting in a wide bandwidth.

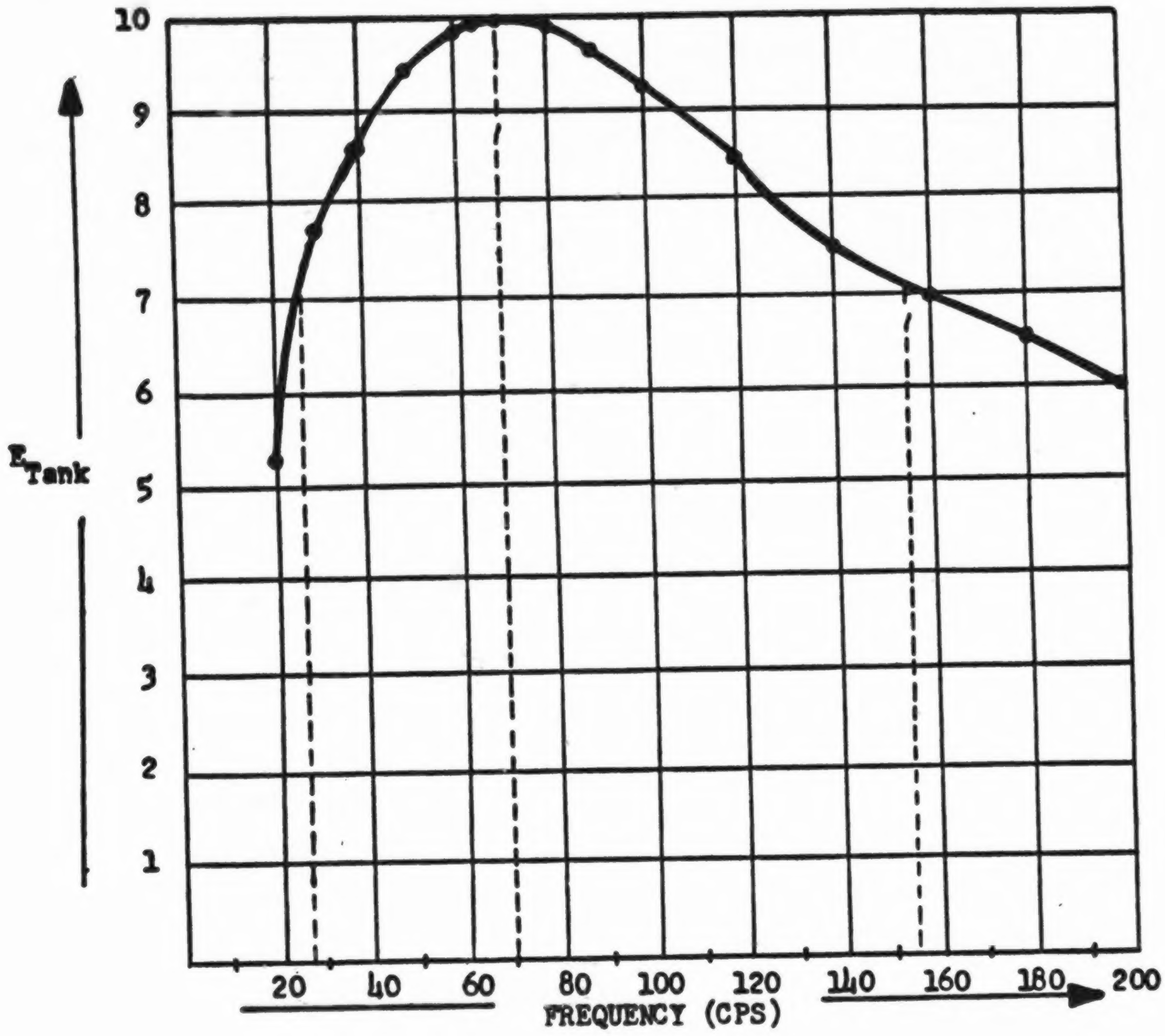


Figure 10

OBJECTIVE c. Identify the tank circuit branch with the greater current when a frequency above or below resonance is applied, using an ac ammeter. Circuit must be identified as inductive or capacitive.

STEP 18. Set the frequency to 20 cycles per second. Measure and record the current through the inductor of the tank circuit.

CURRENT IN INDUCTIVE BRANCH __________ ma.

STEP 19. Measure and record the current through the capacitor of the tank circuit.

CURRENT IN CAPACITIVE BRANCH ____________ ma.

STEP 20. Which branch has the greater current flow? ____________________.

STEP 21. Set the frequency to 200 cycles per second. Measure and record the current through the capacitor of the tank circuit.

CURRENT IN CAPACITIVE BRANCH ________________ ma.

STEP 22. Measure and record the current through the inductor of the tank circuit.

CURRENT IN INDUCTIVE BRANCH ______________ ma.

STEP 23. Which branch has the greater current flow? ____________________

STEP 24. Set the input frequency to resonance. Measure and record the current through the capacitor and inductor branches.

CURRENT IN INDUCTIVE BRANCH ________ _________ ma.

CURRENT IN CAPACITIVE BRANCH ______ __________ ma.

NOTE: These two currents should be equal. If not adjust the frequency until they are. This will be the true resonant frequency.

STEP 25. Leaving your circuit at resonance, measure and record the line current.

LINE CURRENT _________________ ma.

You should have observed the following facts while performing steps 18-25.

a. Below resonance, the circuit is inductive, because the inductive branch has a greater current flow than the capacitive branch.

b. Above resonance, the circuit is capacitive, because the capacitive branch has a greater current flow than the inductive branch.

c. At resonance, the capacitor and inductor have equal current, because this current is flowing back and forth between the two reactors.

d. At resonance, line current is minimum.

Analyzing the given facts, it can be seen that at resonance, the tank passes current back and forth between the capacitor and inductor with very little current supplied by the line. (See Figure 11.)

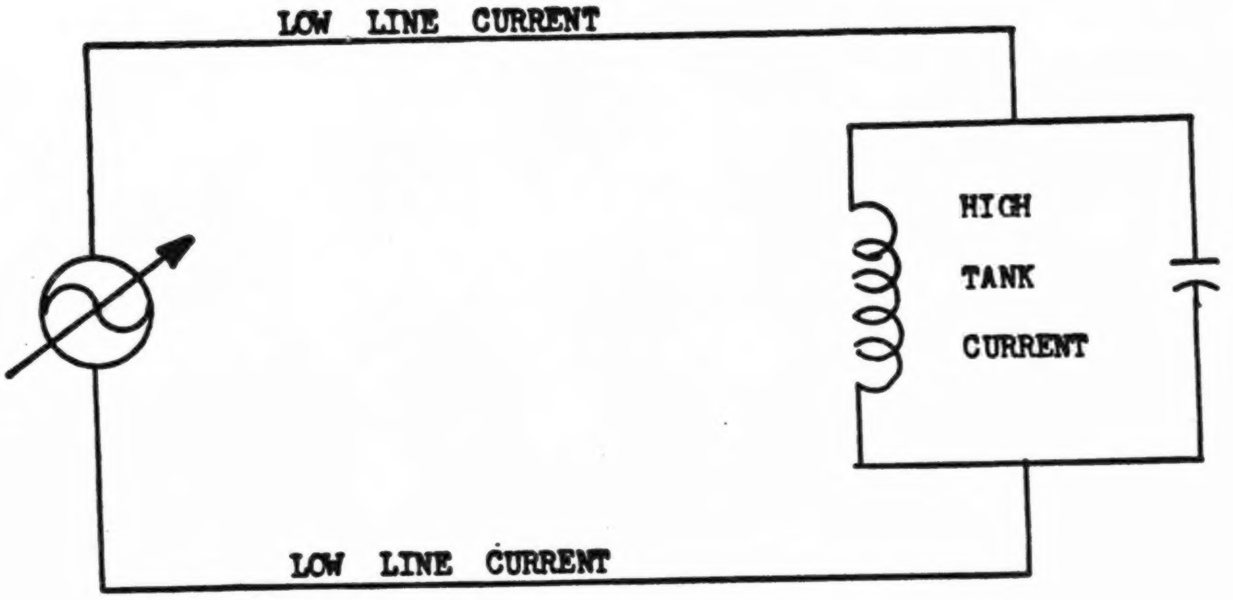

LOW LINE CURRENT
HIGH
TANK
CURRENT
LOW LINE CURRENT

Figure 11

It must be assumed, if the tank circuit had no inherent resistance, that the tank would continue to function when disconnected from a power source. However, the coil as well as the connecting circuitry within the tank has some resistance. Therefore, if the source were disconnected the voltage developed by the tank would "dampen" or die out. (See Figure 12.) Turn on your oscilloscope and allow it to warm up.

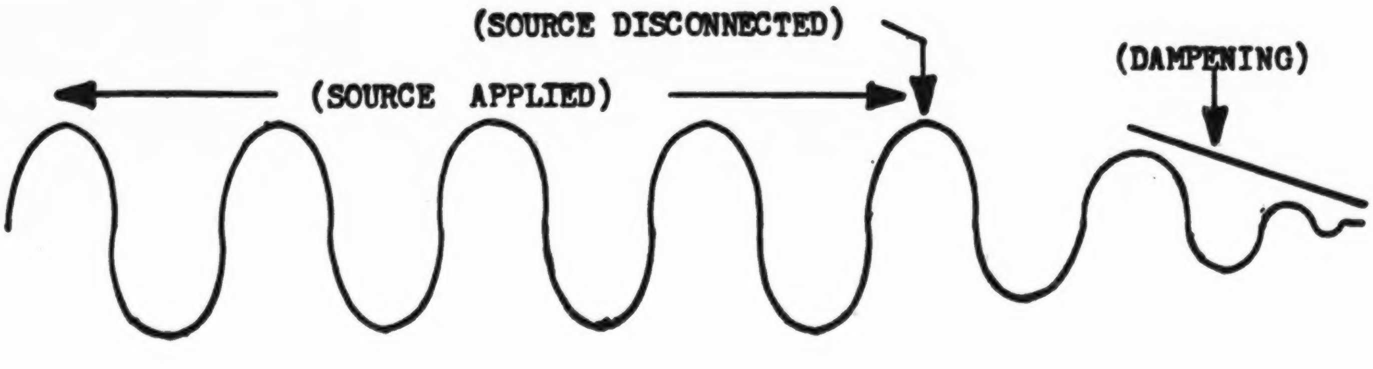

(SOURCE DISCONNECTED)
(DAMPENING)
(SOURCE APPLIED)

Figure 12

STEP 26. Make the following settings on your oscilloscope.

SYNC SELECTOR TO +
SWEEP SELECTOR TO 100/1K
HORIZONTAL GAIN TO 5
SWEEP VERNIER TO 5
VERT ATTEN TO 1
VERTICAL GAIN TO 5
VERT TO AC

STEP 27. Connect the probe across the capacitor.

STEP 28. Disconnect one of the source leads from the sine-generator. Tap this lead to the source several times while watching the scope presentation. The dampening effect should be observed. Minor scope adjustments may be required.

Consider the operation of the tank in an LC circuit.

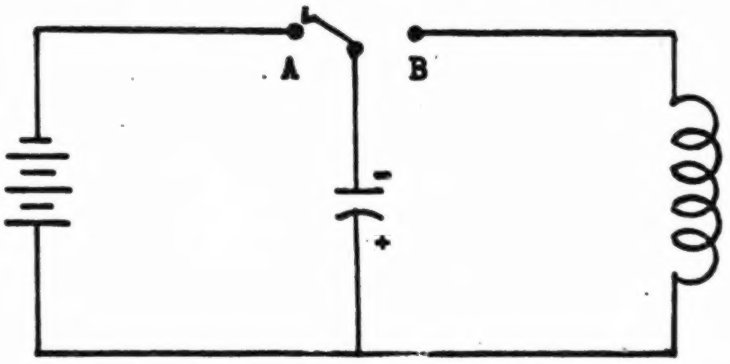


Figure 13

Assume that a charge is placed across the capacitor as shown in Figure 13. Once the switch is changed to position B (See Figure 14), the applied source is removed and completes the circuit between the inductor and capacitor, which is now charged negative on top, positive on bottom.

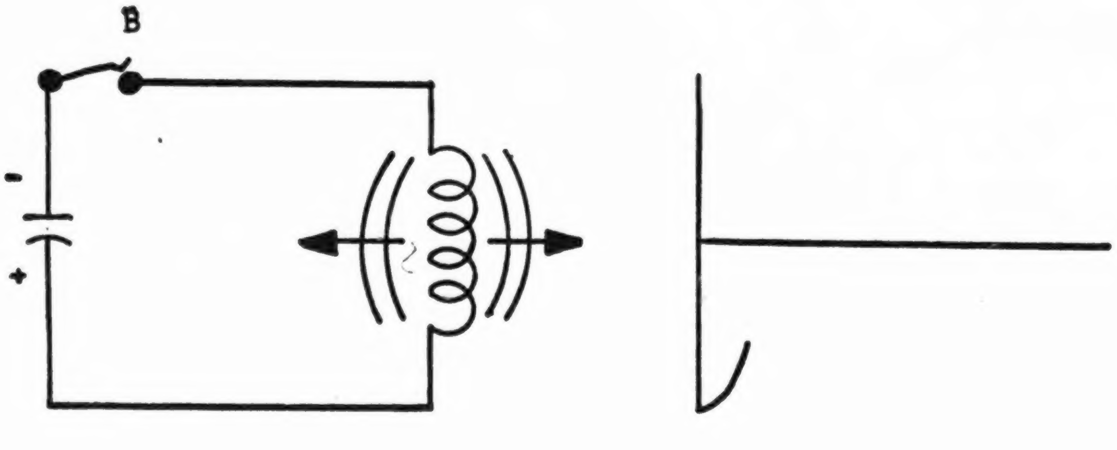


Figure 14

(The following discussion applies to the operation of both series-tuned and parallel-tuned circuits.) By moving the switch to position B, a path is furnished for the excess electrons (current) on the upper plate to flow to the lower plate and neutralize the charge. As current flows through the coil, a magnetic field is built up around the coil. In this manner the electric energy that was first stored by the capacitor is now stored in the magnetic field of the inductor. In Figure 15, the charge of the two plates is shown equalized (no polarity) and a maximum stationary magnetic field exists around the coil.

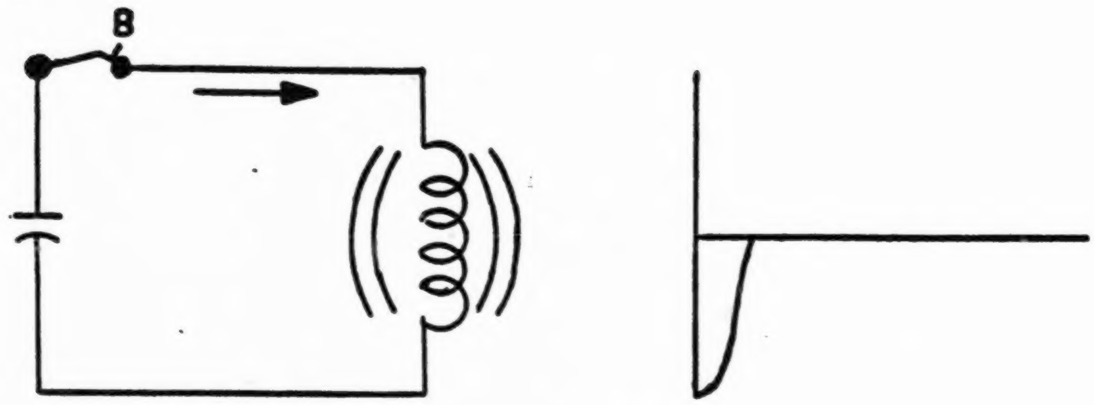


Figure 15

Since the capacitor is completely discharged, the magnetic field starts to collapse. (See Figure 16.)

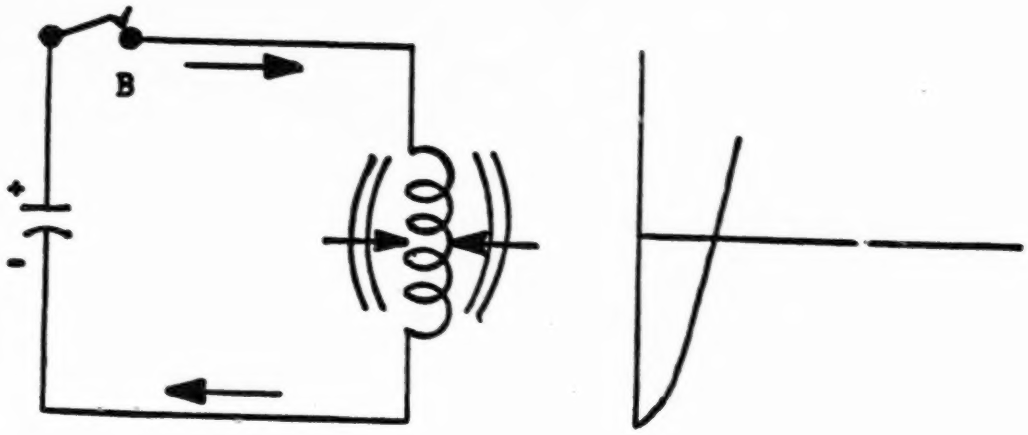


Figure 16

The collapsing field induces a voltage in the coil which tends to cause the current to continue to flow toward the bottom plate.

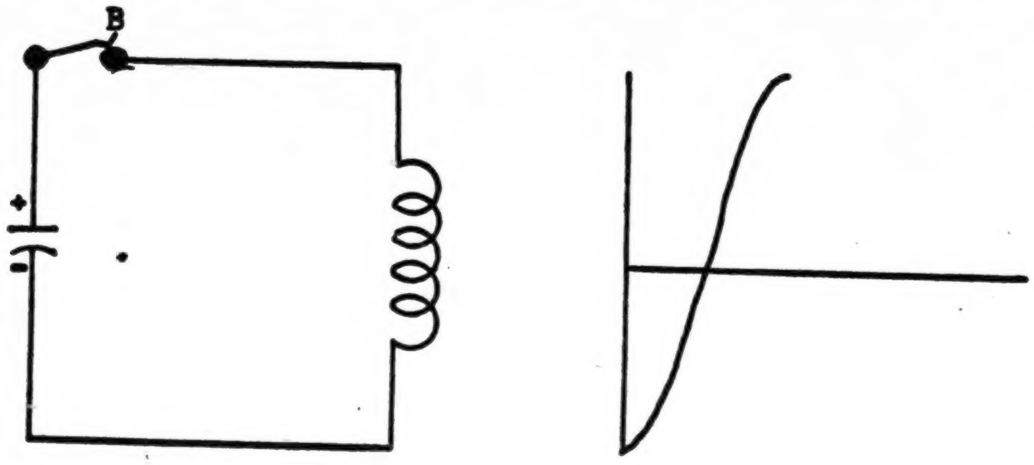


Figure 17

In Figure 17, the magnetic field has completely collapsed, but in doing so it has caused the capacitor to become charged with the opposite polarity to that of the original charge in Figure 13. If the circuit has no resistance, the amount of this charge would be the same as the original charge. However, the coil and the connecting wires have some resistance, and a small amount of energy is dissipated (lost) in the form of heat. Therefore, the charge on the capacitor of Figure 17 is slightly less than the original charge. The capacitor can now start to discharge back up through the coil. This discharge current, (see Figure 18) causes a new magnetic field to be built up around the coil. At Figure 19, the charge on the two capacitor plates has equalized and all of the energy is stored in the magnetic field again.

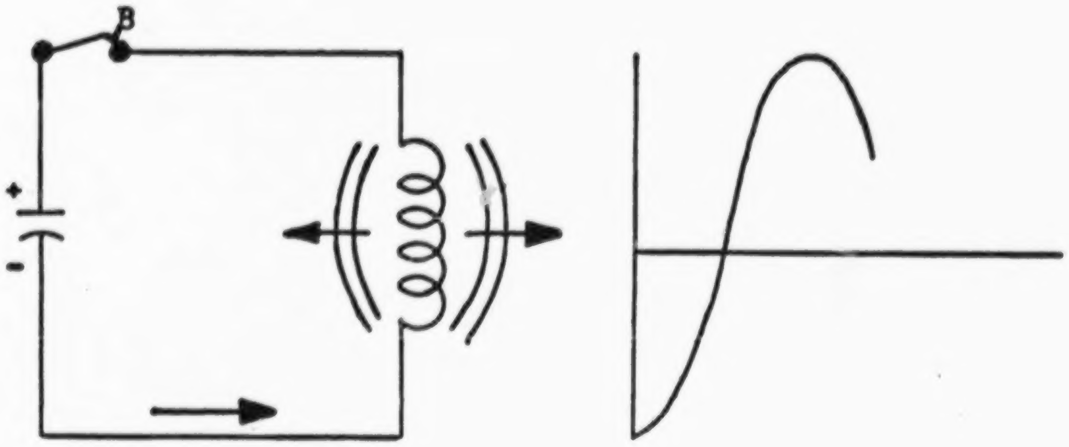


Figure 18

The magnetic field starts to collapse in Figure 20, causing further electron (current) flow toward the upper capacitor plate.

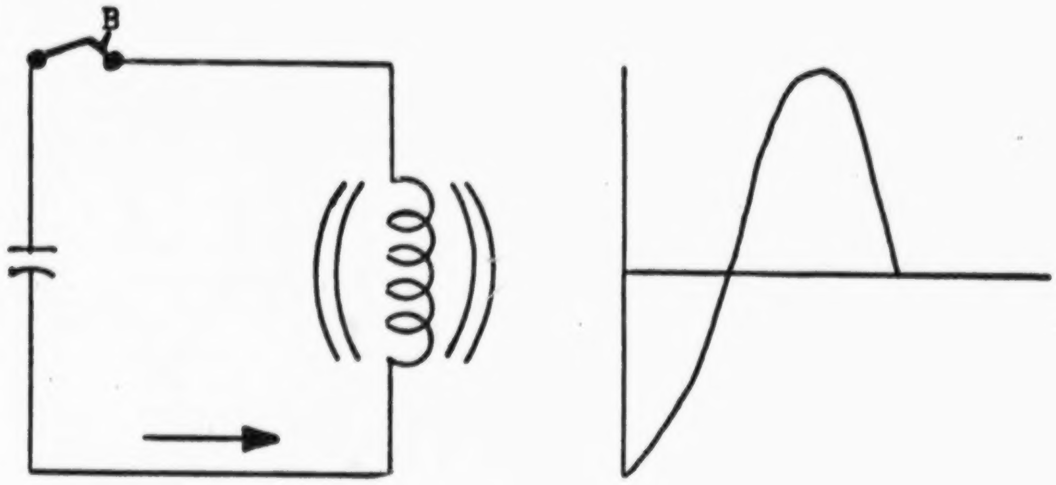


Figure 19

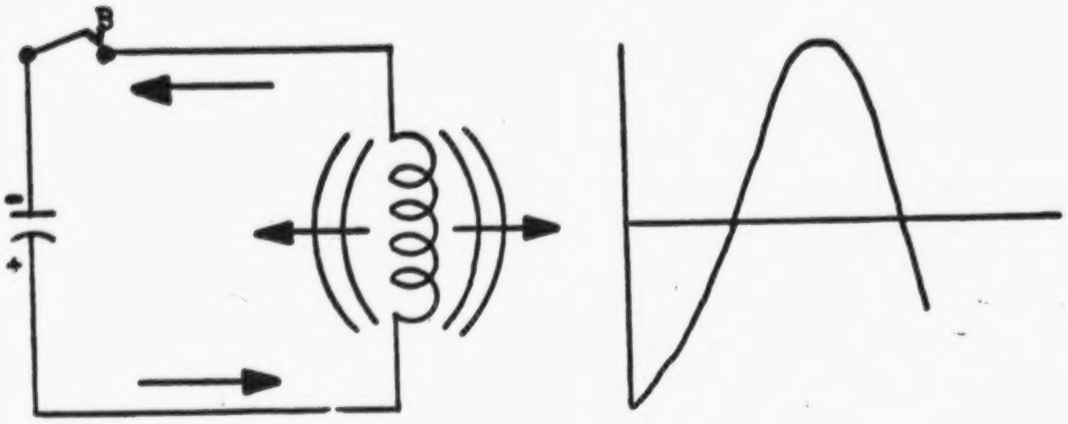


Figure 20

The action of the tank completes one cycle of operation in Figure 21, and the capacitor now has the same polarity of charge that it had in Figure 13.

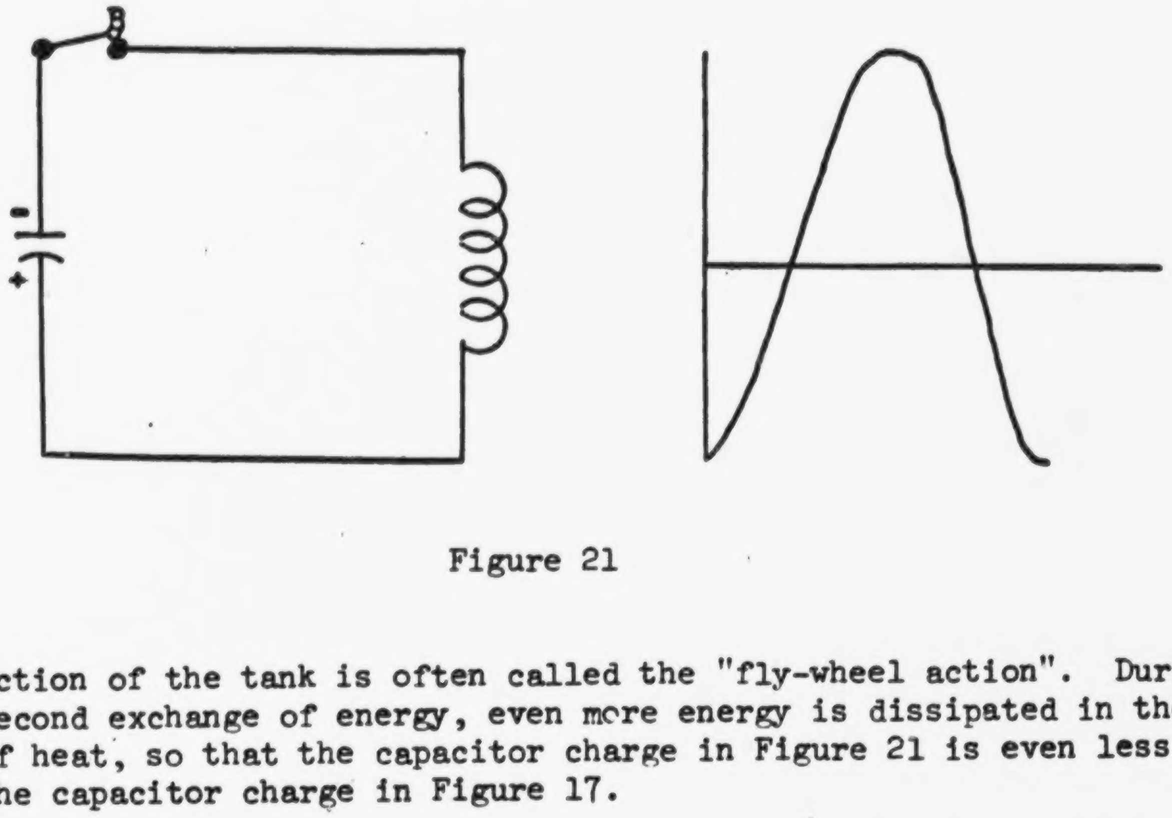


Figure 21

This action of the tank is often called the "fly-wheel action". During this second exchange of energy, even more energy is dissipated in the form of heat, so that the capacitor charge in Figure 21 is even less than the capacitor charge in Figure 17.

If the circuit is not opened, this discharging and charging action (fly-wheel action) will continue until all of the energy in the circuit has been dissipated due to circuit resistance, (dampening).

If it were possible to throw the switch to the battery quickly after each complete cycle (as at Figure 21) to replenish the lost energy, the action would continue indefinitely. This switching action can be accomplished by a transistor or electron tube. When this type of circuit (you will study it later) is constructed, you have an oscillator. The bench sine-wave generator is a circuit of this type.

INSTRUCTOR CHECK:

Match the definition or description on the right with the terms on the left. Place the letters in the blanks provided.

TERM

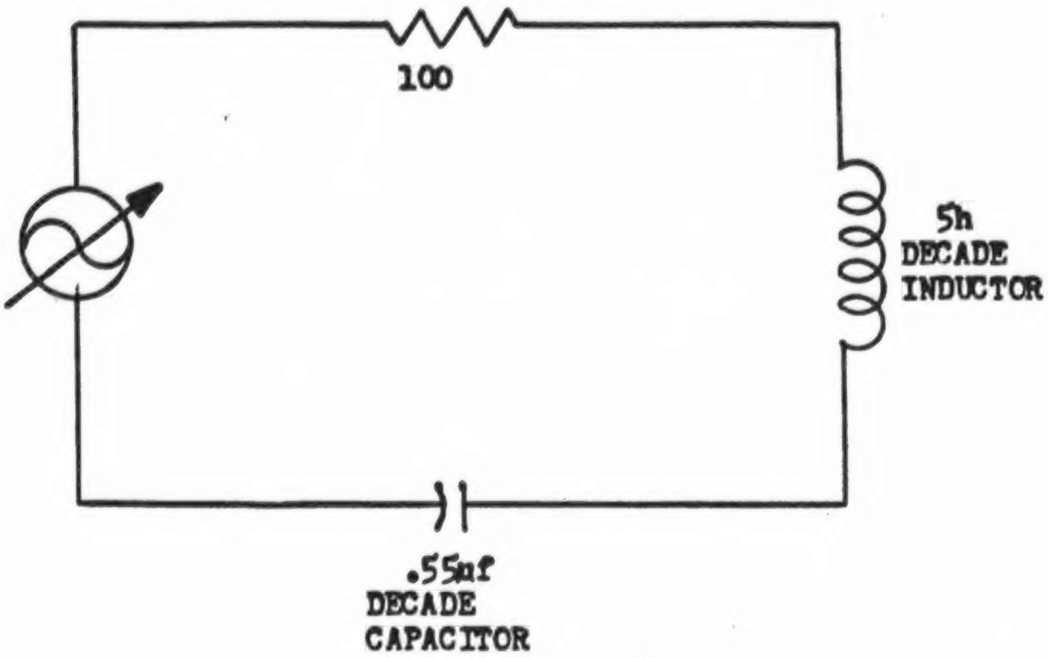
_____ 1. Resonance
_____ 2. Half-Power Points
_____ 3. Selectivity
_____ 4. "High Q"
_____ 5. Bandwidth
_____ 6. Bandpass Frequency
_____ 7. "Low Q"
_____ 8. Impedance
_____ 9. Inductive Circuit (series)
_____ 10. Inductive Circuit (parallel)
_____ 11. Capacitive Circuit (series)
_____ 12. Capacitive Circuit (parallel)
_____ 13. Inductive Reactance
_____ 14. Capacitive Reactance
_____ 15. Tank

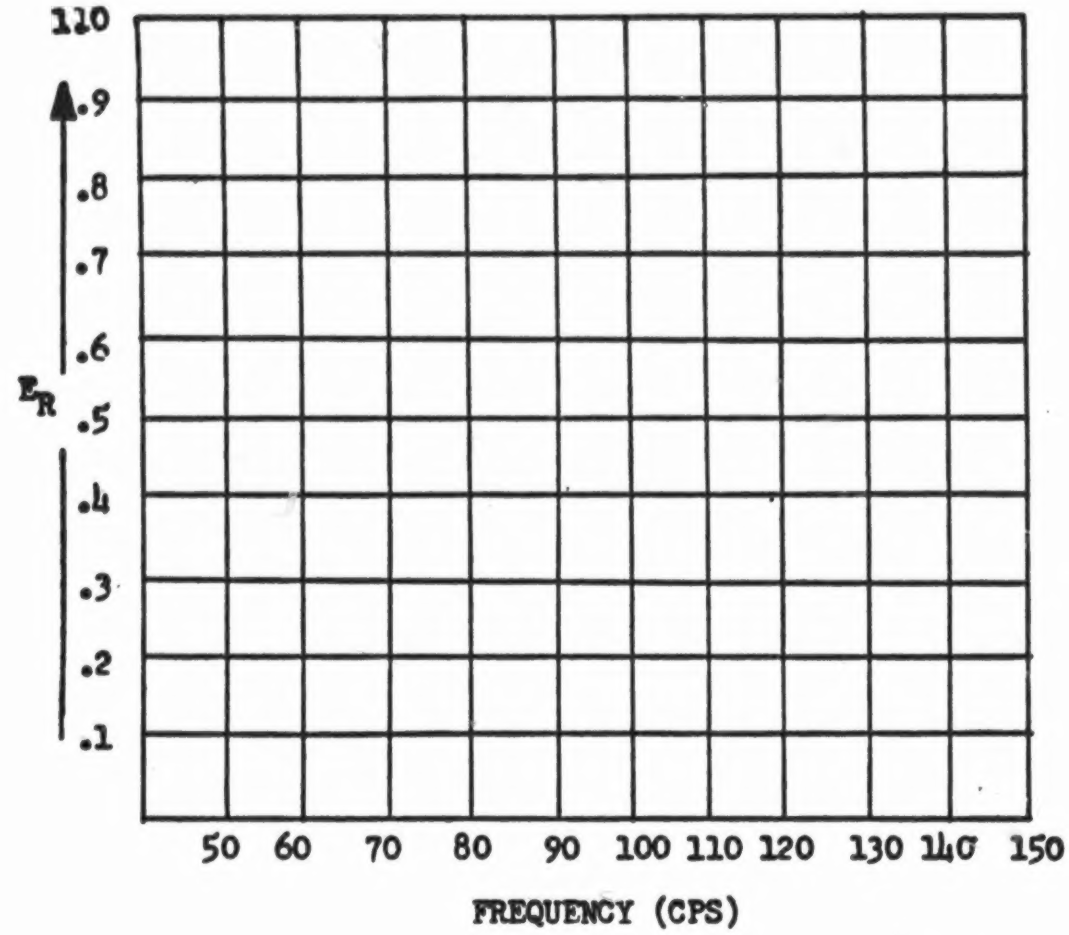
DESCRIPTION

a. The frequencies which develop at least .707 x max voltage or current across a series or parallel tuned circuit.
b. A circuit where X_L is greater than X_C or E_L is greater than E_C.
c. The ability of a tuned circuit to select a very narrow band of frequencies from within a broad band.
d. Opposition offered by a capacitor to the flow of alternating current.
e. A parallel LC circuit.
f. The condition of an RCL circuit when opposition is equal to the resistance of the circuit.
g. An RCL circuit where a larger current flows through the capacitive branch than through the inductive branch.
h. The standard used to determine frequencies with sufficient signal strength.
i. A circuit where X_C is greater than X_L or E_C is greater than E_L.
j. Low gain circuit - poor selectivity.
k. Opposition offered by an inductor to the flow of alternating current.
l. High gain circuit - good selectivity.
m. Total opposition offered by a circuit to alternating current.
n. An RCL circuit where a larger current flows through the inductive branch than through the capacitive branch.
o. The number of cycles that a tuned circuit passes with sufficient gain.
p. The transfer of energy which takes place in a tank.

Have your instructor check your work.

TRAINER CHECK 49. Construct the following series RCL circuit. Set the sine-generator frequency to 25 CPS and adjust the amplitude of the output to 10V.


100
5h
DECADE
INDUCTOR
.55uf
DECADE
CAPACITOR



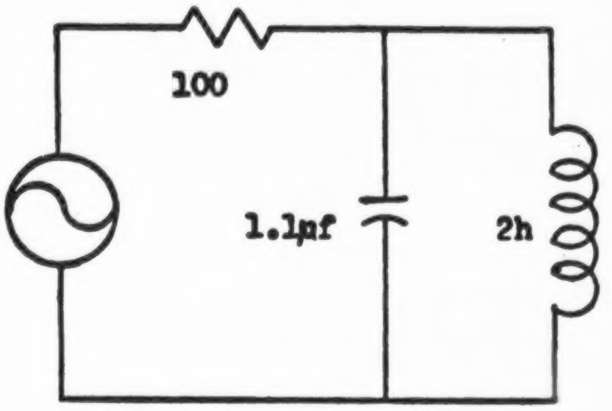
What are the bandpass frequencies for this RCL combination? (You may use the graph for plotting the response curve.)

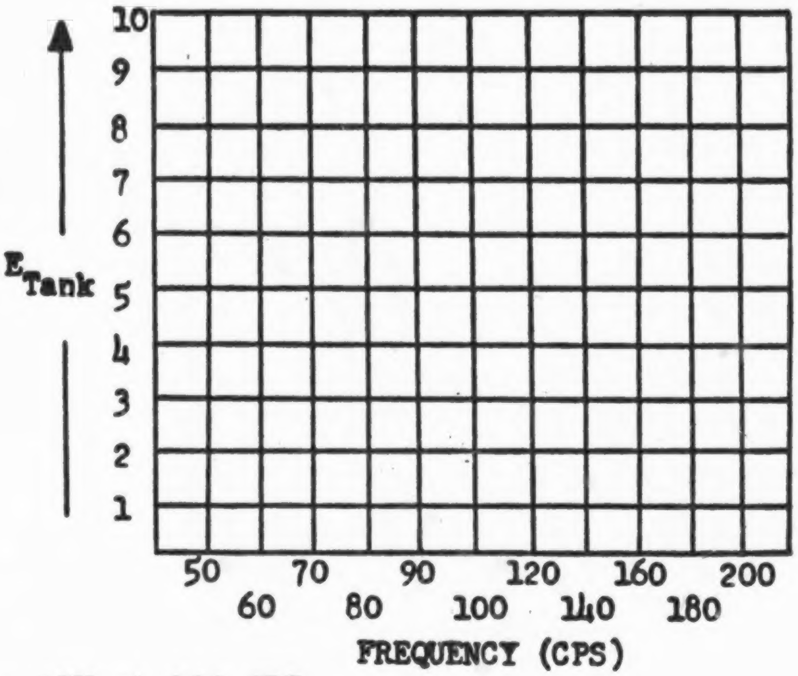
a. 73 - 46 CPS
b. 25 - 142 CPS
c. 104 - 157 CPS
d. 92 - 138 CPS

TRAINER CHECK 50: What is the bandwidth?

a. 21 cycles
b. 69 cycles
c. 53 cycles
d. 46 cycles

TRAINER CHECK 51: Construct the following circuit.





Adjust the sine-generator output to 10V at 100 CPS.

What are the bandpass frequencies for this RCL combination? (You may use the graph for plotting the response curve.)

a. 102 - 193 CPS
b. 33 - 62 CPS
c. 87 - 187 CPS
d. 67 - 167 CPS

TRAINER CHECK 52: What is the bandwidth?

a. 160 cycles
b. 100 cycles
c. 91 cycles
d. 29 cycles

TRAINER CHECK 53: Using the circuit in Trainer Check 52, set the decade induction to 10 h, set the frequency to 160 CPS. The circuit is:

a. resistive.
b. inductive.
c. capacitive.
d. resonant.

TRAINER CHECK 54: Set the frequency to 20 CPS. The circuit is:

a. capacitive.
b. inductive.
c. resonant.
d. resistive.

NOTE: If trainer checks 49 or 50 were missed, review Objective a.

If trainer checks 51 or 52 were missed, review Objective b.

If trainer checks 53 or 54 were missed, review Objective c.

SUMMARY

In determining the bandwidth and bandpass frequencies you plotted a response curve and used measured voltages from an RCL series circuit. You found resonance to be at a minimum impedance and where line current was maximum. The bandwidth was determined by finding the half-power points of the response curve. The half-power points were found by multiplying the voltage drop of the resistors at resonance times .707. A line is drawn across the response curve at this voltage reading, and the points where this line intersects the curve locates the voltage of the half-power points. The bandpass frequencies are the frequencies between the half-power points. These bandpass frequencies give you the bandwidth; which is found by subtracting the lowest frequency from the highest frequency of the half-power points.

You found that the "Q" or quality of a resonant circuit determines the circuit selectivity. The selectivity of a resonant circuit is the ability of the circuit to discriminate between several frequencies that are close together.

The selectivity can also be seen by the steepness of the response curve and the strength of the signal is indicated by the height of the curve. Therefore, high Q will indicate good selectivity, while low Q will indicate poor selectivity. You also saw that a high Q circuit will have a higher gain, narrower bandwidth, and better selectivity than a low Q.

In the parallel LC circuit you had high impedance to the resonance frequency which resulted in a high voltage drop across the tank. The steepness of the amplitude indicated the Q, again, high Q, the better the selectivity. In the parallel LC circuit you also found that at resonance the line current was minimum, while the tank current was high.

In analyzing the tank circuit operation at resonance a fly-wheel action can be seen; the current passes back and forth between L and C until the energy is consumed by the heat generated within the circuit. If this circuit is allowed to run by triggering it with a transistor you will have an oscillator.

Additional information on resonance may be found in your Basic Electricity Text, Chapter 21.

APPENDIX G

SAMPLE PERFORMANCE TEST

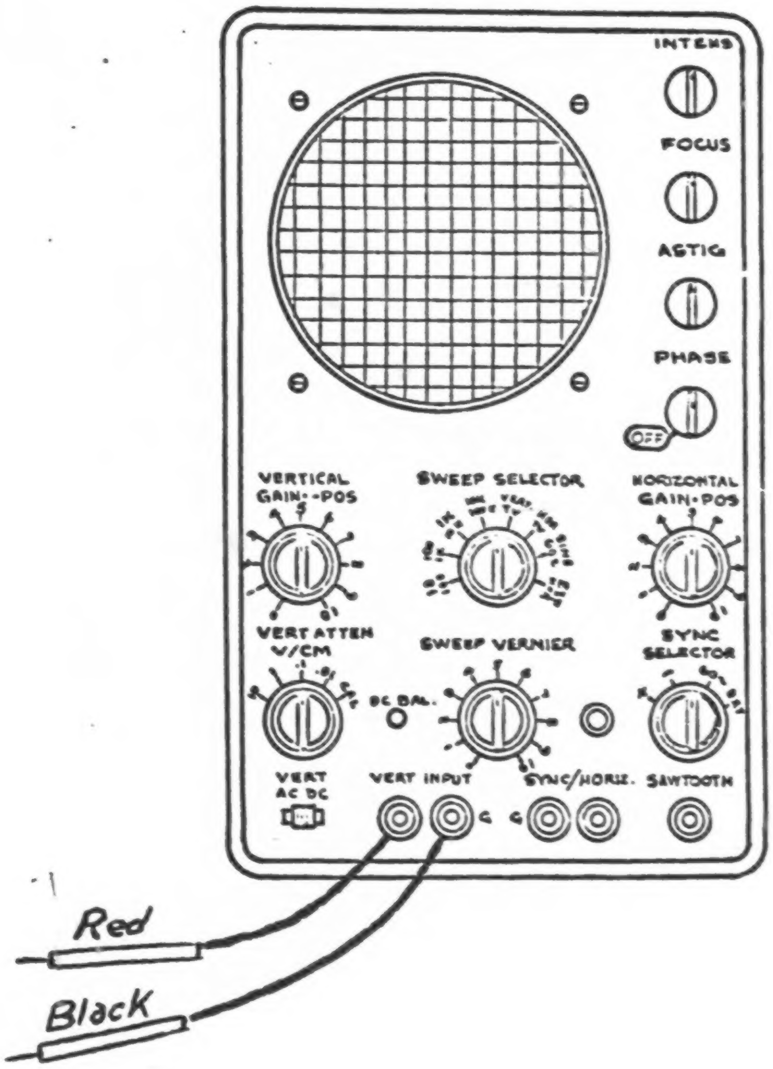
Quincy Vocational-Technical School Electro-Electronics Department
Project ABLE

Student Performance Test

(Projects 11-13)

Name ______________________________ Date ______________________________

11a. Identify the common, horizontal, and vertical controls of the oscilloscope below.


INTENS
FOCUS
ASTIG
PHASE
OFF
VERTICAL GAIN--POS
SWEEP SELECTOR
HORIZONTAL GAIN-POS
VERT ATTEN V/CM
DC BAL.
SWEEP VERNIER
SYNC SELECTOR
VERT AC DC
VERT INPUT
G
G
SYNC/HORIZ.
SAWTOOTH
Red
Black

Insert jumpers on Trainer 1 between 3b and 3c, between 3e and 3f, between 4b and 4c, and between 4e and 4f. Connect the LVDC power supply, + to 1A and - to 1G and adjust it for 13 vdc.

11b. Measure the voltage between 3b and 4d, using the oscilloscope only.

E = 2.3 4.4 8.7 10.2 vdc

11c. The polarity relationship is

3b + - 4e + -

12a. Determine the condition of the indicated diodes in the test assortment using the oscilloscope, diode tester, and trace patterns.

Diode	Condition	
1	Good	Bad
2	Good	Bad
3	Good	Bad
4	Good	Bad
5	Good	Bad

12b. Using only a VTVM, VOM, Soldering iron, and Trainer #1, connect a circuit to demonstrate to the instructor the temperature coefficient of the diode located at 6bc.

Instructor's Evaluation of Demonstration S ______ U ______

Student's Observation (Circle one)

1. Current	Increased	Decreased
2. Temperature Coefficient	Positive	Negative

13a. Select definition of temperature coefficient from those listed below.

a. Voltage variations on a diode cause temperature changes.
b. Resistance variations on a diode cause temperature changes.
c. Temperature variations on a diode cause voltage changes.
d. Temperature variations on a diode cause resistance changes.

APPENDIX H

SAMPLE OCCUPATIONAL READINESS RECORD

Project ABLE/ Quincy Public Schools/ American Institutes for Research

OCCUPATIONAL READINESS RECORD

To The Employer:

This occupational readiness record is both an inventory of the training course content and level of proficiency or achievement demonstrated by the graduate. Graduates can provide potential employers with more complete performance check lists which itemize in great detail the skills and knowledge in which he has demonstrated proficiency. It is recognized that persons working at the specified occupational level will function with direction and assistance from superiors. As a part of his training, the graduate has learned to expect appropriate instructions with each assigned task. Furthermore, the graduate should understand that he lacks the authority and training to perform certain functions and operations. He will expect and seek supervision, assistance and direction where appropriate. Note that the job tasks as identified are basic to the next higher or more sophisticated job level. Work experience and further training may qualify the graduate for more complicated tasks, a new job title, and higher pay.

All graduates receiving this document have satisfactorily demonstrated to the training staff their ability to work safely, understand and carry out instructions, and cooperate with other employees. This document also attests to their punctuality, reliability, and general work habits.

Key to Proficiency Code:

Level L: Limited Skill--does simple parts of task using required tools, but requires instruction and supervision to do most parts of the job. Identifies parts by name, knows simple facts about the job.

Level M: Moderate Skill--requires help on some parts, but can use most tools and special equipment needed. Knows work procedures but may not meet minimum demands for speed or accuracy.

Level S: Skilled--understands operating principles and accomplishes all parts of task with only spot checks of finished work. Meets minimum demands for speed and accuracy.

3

JOB FAMILY: Electro-Electronics and Related Occupations

EXIT LEVEL: Electronics Mechanic (828.281) and Related Occupations

Name ______________________ Date ______________________

Soc. Sec. No. ______________________ Length of Training ______________________

Certified by ______________________ Title ______________________

Comments ____

____

L	M	S		
☐	☐	☐	(1) a.	Measures resistance, using the VOM multimeter.
☐	☐	☐	b.	Determines the ohmic value of resistors, using the color code.
☐	☐	☐	c.	Calculates the minimum and maximum acceptable values of a resistor, using the color code.
☐	☐	☐	(2) a.	Solders an electrical component to a printed circuit board, using a soldering iron, long-nose pliers, and solder.
☐	☐	☐	b.	Solders a solid-state diode to a printed circuit board, using a soldering iron, long-nose pliers, solder, and heat sink.
☐	☐	☐	(3) a.	Measures DC voltage, using the VOM multimeter.
☐	☐	☐	b.	Measures DC current, using the VOM multimeter.
☐	☐	☐	c.	States the change in E, I, or R when one is changed, using Ohms Law.
☐	☐	☐	(4) a.	Identifies series, parallel, and series-parallel circuits from schematics.
☐	☐	☐	b.	Measures DC voltage in a series circuit, using the VOM multimeter.
☐	☐	☐	c.	Measures DC voltage in a parallel circuit, using the VOM multimeter.
☐	☐	☐	d.	Measures DC voltage in a series-parallel circuit, using the VOM multimeter.
☐	☐	☐	e.	Measures DC current in a series circuit, using the VOM multimeter.

L	M	S			
☐	☐	☐		f.	Measures DC current in a parallel circuit, using the VOM multimeter.
☐	☐	☐		g.	Measures DC current in a series-parallel circuit, using the VOM multimeter.
☐	☐	☐		h.	Measures single, multiple, or total resistance values in a series circuit, using the VOM multimeter.
☐	☐	☐		i.	Measures individual, branch, or total resistance values in a parallel network, using the VOM multimeter.
☐	☐	☐		j.	Measures individual, branch, or total resistance values in a series-parallel circuit, using the VOM multimeter.
☐	☐	☐	(5)	a.	Measures AC voltages using the VOM multimeter.
☐	☐	☐	(6)	a.	Locates the malfunctioning component and identifies the probable cause, given a schematic, malfunction symptom, and using the VOM multimeter.
☐	☐	☐	(7)	a.	Measures resistance, using the VTVM.
☐	☐	☐		b.	Measures DC voltage, using the VTVM.
☐	☐	☐		c.	Measures AC voltage, using the VTVM.
☐	☐	☐	(8)	a.	Identifies the anode and the cathode of a solid-state diode, using an ohmmeter.
☐	☐	☐		b.	Determines the condition of a solid-state diode by performing a forward-reverse resistance check, using an ohmmeter.
☐	☐	☐		c.	Determines diode biasing, using a schematic.
☐	☐	☐	(9)	a.	Determines the potential difference between, and and the polarity of, two points in a DC circuit (not including ground) using a voltmeter.
☐	☐	☐		b.	Measures positive and negative DC voltage with respect to ground, using a voltmeter.
☐	☐	☐	(10)	a.	Calculates the potential difference between the open terminals of a bridge circuit, using Ohm's law.

L	M	S			
☐	☐	☐		b.	Determines the potential difference between, and the polarity of, the open terminals of a bridge circuit using a VOM or VTVM.
☐	☐	☐		c.	Calculates the amount and direction of current flow through the galvanometer of a wheatstone bridge, using a schematic diagram.
☐	☐	☐		d.	Determines the amount and direction of current flow through the galvanometer of a wheatstone bridge using a galvanometer.
☐	☐	☐		e.	Calculates the voltage across the current through the fifth resistor in a five resistor bridge circuit, using Thevenin's Theorem.
☐	☐	☐	(11)	a.	Identifies the common, horizontal, and vertical controls of an oscilloscope, using a pictorial diagram.
☐	☐	☐		b.	Measures potential difference, using the oscilloscope.
☐	☐	☐		c.	Determines the polarity relationship between two points of a DC series circuit (not including ground) using the oscilloscope.
☐	☐	☐	(12)	a.	Determines the condition of solid-state diodes, using the diode tester, oscilloscope, and trace patterns.
☐	☐	☐	(13)	a.	Selects the definition of temperature co-efficient from a list of four.
☐	☐	☐		b.	Determines the change in circuit current when a diode (with negative temperature co-efficient) is subjected to heat, using an ammeter and a soldering iron.
☐	☐	☐	(14)	a.	Locates the malfunctioning component and identifies the probable cause, given a schematic, malfunction symptom, and using available test equipment.
☐	☐	☐	(15)	a.	Determines the type of transistor, (NPN or PNP) using an ohmmeter.
☐	☐	☐		b.	Determines the apparent condition of transistors, using an ohmmeter.
☐	☐	☐		c.	Determines the conducting state of a transistor, using the shorting method.

L	M	S			
☐	☐	☐		d.	Determines the conducting state of a transistor, using a voltmeter.
☐	☐	☐	(16)	a.	Determines the effect of increased light on the output voltage of a photovoltaic cell, using the available test equipment and flashlight.
☐	☐	☐		b.	Determines the effect of a change in bias on the output voltage of a transistor, using available test equipment.
☐	☐	☐	(17)	a.	Determines the condition of a transistor using the oscilloscope, transistor tester, and trace patterns.
☐	☐	☐	(18)	a.	Identifies the precautions used against heat on printed circuits.
☐	☐	☐		b.	Identifies the preliminary troubleshooting steps for printed circuits.
☐	☐	☐	(19)	a.	Identifies the various characteristics of an AC waveform, using a list of terms and a pictorial diagram.
☐	☐	☐		b.	Measures peak to peak voltage, using the oscilloscope.
☐	☐	☐		c.	Calculate the effective value of an AC waveform (voltage or current) using the formula for E effective.
☐	☐	☐		d.	Determines the DC reference of an AC voltage, using the oscilloscope.
☐	☐	☐		e.	Determines voltage, current and resistance, using Ohm's law relationships or available test equipment.
☐	☐	☐		f.	Identifies the phase relationship between E_A and E_R of a resistive circuit using the oscilloscope.
☐	☐	☐	(20)	a.	Determines the frequency of an AC signal, using the oscilloscope.
☐	☐	☐		b.	Determines the frequency of a square wave using the oscilloscope.
☐	☐	☐	(21)	a.	Determines the condition of solid-state diodes, using the oscilloscope.
☐	☐	☐		b.	Determines the condition of transistor, using the oscilloscope.

L	M	S			
☐	☐	☐	(22)	a.	Determines the effect of change in inductance on current, using a series RL circuit, a variable inductor, and an a-c ammeter.
☐	☐	☐		b.	Determines the effect of change in frequency on current, using a series RL circuit and a-c ammeter.
☐	☐	☐		c.	Finds inductive reactance (X_L) with given values of f and L using a series RL circuit, VTVM, and a-c ammeter.
☐	☐	☐		d.	Determines the phase relationship of circuit current with respect to applied voltage using a series RL circuit and oscilloscope.
☐	☐	☐		e.	Finds impedance (Z) of a given RL circuit, using a VTVM and a-c ammeter.
☐	☐	☐		f.	Determines the effect of change in capacitance on current, using a series RC circuit, variable capacitor, and a-c ammeter.
☐	☐	☐		g.	Determines the effect of change in frequency on current, using a series RC circuit and a-c ammeter.
☐	☐	☐		h.	Finds capacitive reactance (X_C)with given values of f and C using a series RC circuit, VTVM, and a-c ammeter.
☐	☐	☐		i.	Determines the phase relationship of circuit current with respect to applied voltage using a series RC circuit and oscilloscope.
☐	☐	☐		j.	Finds impedance (Z) of a given RC circuit, using a VTVM and a-c ammeter.
☐	☐	☐		k.	Determines the effect on current, when capacitance is added in parallel using a parallel circuit, variable capacitor, and a-c ammeter.
☐	☐	☐		l.	Determines the effect on current, when inductance is added in parallel using a parallel circuit, variable inductor, and an a-c ammeter.
☐	☐	☐	(23)	a.	Determines the resonant frequency using a series RCL circuit, variable frequency source and a-c ammeter.
☐	☐	☐		b.	Tunes an inductor and capacitor (LC) for resonance using a series RCL circuit, given frequency and a-c ammeter.

L	M	S			
☐	☐	☐		c.	Determines the phase relationship of current with respect to applied voltage in a series RCL circuit, using the oscilloscope.
☐	☐	☐		d.	Measures E_L and E_C to find circuit condition, (above, below, or at resonance) using a series RCL circuit and VTVM.
☐	☐	☐	(24)	a.	Calculates the impedance of a parallel RL circuit, using measured values of E_A and I (line).
☐	☐	☐		b.	Determines the effect of a change in frequency on the line current in a parallel RL circuit, using an a-c ammeter.
☐	☐	☐		c.	Determines the effect of a change in inductance on the line current in a parallel RL circuit, using an a-c ammeter.
☐	☐	☐		d.	Determines the effect of a change in capacitance on the line current in a parallel RC circuit, using an a-c ammeter.
☐	☐	☐		e.	Determines the effect of a change in frequency on the line current in a parallel RC circuit, using an a-c ammeter.
☐	☐	☐		f.	Calculates the impedance of a parallel RC circuit using measured values of E_A and I (line).
☐	☐	☐		g.	Determines the effect of frequencies above, below, and at resonance on line current of a parallel RCL circuit, using an a-c ammeter.
☐	☐	☐	(25)	a.	Determines the "bandwidth" and "bandpass frequencies" of a series RCL circuit, using a VTVM.
☐	☐	☐		b.	Determines the "bandwidth" and "bandpass frequencies" of a parallel RCL circuit, using a VTVM.
☐	☐	☐		c.	Identifies the tank circuit branch with the greater current when a frequency above or below resonance is applied, using an a-c ammeter.
☐	☐	☐	(26)	a.	Identifies the components of a full wave rectifier, from a schematic.
☐	☐	☐		b.	Obtains the output wavershape of a full wave rectifier using the oscilloscope.
☐	☐	☐		c.	Identifies Pi, capacitive, inductive, and "T" type filters from a schematic.

L	M	S			
☐	☐	☐		d.	Locates the malfunctioning component in a full wave rectifier and identifies the probable cause, using the available test equipment.
☐	☐	☐	(27)	a.	Obtains the output waveshape of a voltage doubler, using the oscilloscope.
☐	☐	☐		b.	Locates the malfunctioning component in a voltage doubler, using the available test equipment.
☐	☐	☐	(28)	a.	Identifies the components and their function in a bridge rectifier, using a schematic.
☐	☐	☐		b.	Obtains the output waveshape of a bridge rectifier using the oscilloscope.
☐	☐	☐		c.	Locates the malfunctioning component in a bridge rectifier, using the available test equipment.
☐	☐	☐	(29)	a.	Identifies zener diode symbols, from a schematic diagram.
☐	☐	☐		b.	Identifies the voltage regulator tube symbol, from a schematic diagram.
☐	☐	☐		c.	Obtains the waveshape across a zener diode, using the oscilloscope.
☐	☐	☐	(30)	a.	States the effect of a change in input voltage on the output voltage of a regulated DC power supply using a schematic.
☐	☐	☐		b.	States the effect of a change in load resistance on the output voltage of a regulated DC power supply using a schematic.
☐	☐	☐	(31)	a.	Identifies the three basic amplifier configurations from schematics.
☐	☐	☐		b.	Selects the characteristics of a common base amplifier from a given list.
☐	☐	☐		c.	Selects the characteristics of a common emitter amplifier from a given list.
☐	☐	☐		d.	Selects the characteristics of a common collector amplifier from a given list.
☐	☐	☐	(32)	a.	Selects the characteristics of an audio amplifier from a given list.

L	M	S			
				b.	Identifies the various types of amplifier coupling from schematic.
				c.	Determines if the RC coupling in an audio amplifier is adequate, using the oscilloscope.
				d.	Locates the malfunctioning component of an audio amplifier, and identifies the probable cause, using the available test equipment.
			(33)	a.	Selects the characteristics of a push-pull amplifier from a given list.
				b.	Identifies the malfunctioning component of a push-pull amplifier from a given schematic and symptoms.
			(34)	a.	Selects the characteristics of a video amplifier from a given list.
				b.	Identifies the components that provide low frequency compensation on a schematic.
				c.	Identifies the components that provide high frequency compensation in a video amplifier on a schematic.
			(35)	a.	Determines the condition of vacuum tubes, using the tube tester.
				b.	Identifies the elements of vacuum tubes from schematic symbols.
				c.	Identifies multi-unit tubes from schematic symbols.
				d.	Number tube and socket pins using pictorial diagrams.
				e.	Identifies gas filled tubes from schematic symbols.
			(36)	a.	Identifies the major parts of an oscillator, on a given block diagram.
			(37)	a.	Selects from a list of statements, the one which correctly identifies the path of current flow through a crystal oscillator.
			(38)	a.	Identifies the path of current flow through a Hartley oscillator, using a schematic.
				b.	Obtains the output waveshape of a Hartley oscillator using the oscilloscope.

L	M	S			
☐	☐	☐	(39)	a.	Identifies the path of current through a blocking oscillator, using a schematic.
☐	☐	☐		b.	Obtains the output waveshape of a blocking oscillator using the oscilloscope.
☐	☐	☐	(40)	a.	Identifies the components controlling the frequency of the astable multivibrator from an actual circuit.
☐	☐	☐		b.	Finds the frequency of an astable multivibrator using the oscilloscope and the formula f = 1/t.
☐	☐	☐		c.	Synchronizesan astable multivibrator using an external source. The multivibrator must be stable at the source frequency as observed on the oscilloscope.
☐	☐	☐		d.	Selects characteristics of the astable multivibrator from a listing.
☐	☐	☐		e.	Obtains the output of a monostable multivibrator using an oscilloscope.
☐	☐	☐		f.	Obtains the output of a Bistable multivibrator using an oscilloscope.
☐	☐	☐		g.	Selects the application of a Bistable multivibrator when externally triggered from a listing.
☐	☐	☐	(41)	a.	Locates the malfunctioning component in a Bistable multivibrator and identifies the probable cause using the available test equipment.
☐	☐	☐		b.	Locates the malfunctioning component in a monostable multivibrator and identifies the probable cause (using the probable cause) using the available test equipment.
☐	☐	☐		c.	Locates the malfunctioning component in an astable multivibrator and identifies the probable cause using the available test equipment.
☐	☐	☐	(42)	a.	Determines the type of time constant in an RC or RL circuit given R, C or L and the period of the input.
☐	☐	☐		b.	Obtains the output of a differentiating circuit using the oscilloscope. Selects from a list of waveshapes the one which most closely resembles the oscilloscope display and the type of time constant associated with it.

L	M	S			
☐	☐	☐		c.	Obtains the output of an integrating circuit, using the oscilloscope. Selects from a list of waveshapes the one which most closely resembles the oscilloscope display and the type of time constant associated with it.
☐	☐	☐	(43)	a.	Determines whether or not a gating circuit will accept a negative trigger pulse, using a VOM and negative pulse generator.
☐	☐	☐		b.	Determines the type of gate that will operate a given circuit, using a schematic. (OR and AND)
☐	☐	☐		c.	Determines the type of gate that will operate a given circuit, using a schematic. (NOR and NAND)
☐	☐	☐	(44)	a.	Converts numbers in the binary system to their equivalent in the decimal system.
☐	☐	☐		b.	Determines what binary digits will give a specific decimal value.
☐	☐	☐	(45)	a.	Matches terms of electromagnetism to their correct definitions.
☐	☐	☐		b.	Labels the major parts of a relay on a given pictorial diagram.
☐	☐	☐		c.	Identifies the malfunctioning component in a relay circuit and the probable cause, using the available test equipment.
☐	☐	☐	(46)	a.	Selects the characteristics of motors, from a given schematic.
☐	☐	☐		b.	Identifies series, shunt, and compound wound motors, from given schematics.
☐	☐	☐		c.	Selects the characteristics of bi-directional DC motors, from a given list.
☐	☐	☐	(47)	a.	Adjusts a transmitter synchro (1/3) to electrical zero using a VOM multimeter.
☐	☐	☐		b.	Adjusts a control transformer (1/3) to electrical zero using a VOM multimeter.
☐	☐	☐		c.	Identifies basic units of a servo system from a block diagram.

L	M	S			
			(48)	a.	Selects the functional characteristics of an analog computer from a given list.
			(49)	a.	Selects the operating characteristics of a saturable reactor from a given list.
				b.	Selects the operating characteristics of a magnetic amplifier from a given list.
			(50)	a.	Identifies the symbol for a silicon controlled rectifier within a given circuit schematic.
				b.	Labels the elements of a silicon controlled rectifier on a given schematic.
				c.	Selects the functional characteristics of a SCR from a given list.
			(51)	a.	Identifies the symbol for a unijunction transistor within a given circuit schematic.
				b.	Selects the functional characteristics of a unijunction circuit from a given list.
				c.	Obtains the output waveshape of a unijunction transistor circuit using the oscilloscope. Selects from a list of waveshapes the one which most closely resembles the oscilloscope display.
			(52)	a.	Identifies the current path in a basic sweep generator circuit using a schematic.
				b.	Determines the effect of changing the sweep capacitor size on the output amplitude of a sweep generator using the oscilloscope.
				c.	Determines the effect of changing the input frequency on the output linearity of a sweep generator using the oscilloscope.
			(53)	a.	Matches the output waveshapes of limiters, clampers, and choppers with the appropriate circuit, from a given list of waveshapes and a list of circuits.
				b.	Obtains the output waveshape of a limiter, using the oscilloscope. Selects the waveshape which most closely resembles the oscilloscope display.
				c.	Obtains the output waveshape of a clamper using the oscilloscope. Selects the waveshape which most closely resembles the oscilloscope display.

L	M	S		
☐	☐	☐		d. Selects the characteristics of an ac chopper from a given list.
☐	☐	☐	(54)	a. Identifies the symbol for a photovoltaic cell and a photoresistor from a given list.
☐	☐	☐		b. Selects the characteristics of a photovoltaic cell from a given list.
☐	☐	☐		c. Selects the characteristics of a photoresistor from a given list.
☐	☐	☐		d. Determines the voltage across a photovoltaic cell at maximum light using a VOM and a flashlight.
☐	☐	☐		e. Calculates the resistance of a photoresistor receiving maximum light, from measured values of voltage across and current through the photoresistor, using a flashlight and a VOM.